

## FORAMINIFERA AND THE STRATIGRAPHY OF THE WESTERN VICTORIAN CRETACEOUS SEDIMENTS

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### Abstract

This paper gives the results of a detailed examination of the foraminiferal faunas of the W. Victorian Cretaceous rocks. The study is based on bore material, as the marine Cretaceous rocks have not been recognized from outcrop in Victoria. Primarily the study was taxonomic, but an analysis of the vertical and lateral distribution of species resulted in the establishment of a stratigraphic framework and a depositional history of the sediments.

Marine Cretaceous sedimentation commenced in the Cenomanian or Turonian (Upper Cretaceous) with the deposition of detrital material. Foraminifera are not present at the base of the section, probably because of deleterious chemical conditions. With the deposition of finer grained dark mudstones, Foraminifera appear and the species present indicate a Turonian age. These Turonian sediments are limited in areal distribution and the faunas are inhibited by anaerobic conditions due probably to restriction of water circulation, under 'barred basin conditions'. Dark mudstone deposition continued into the Senonian and the areal extent of the deposits increased. The highest dark mudstones contain planktonic faunas and uninhibited benthonic faunas suggesting that water circulation was not restricted, probably due to the removal of off-shore barriers. Contemporaneously with the deposition of the Senonian dark mudstone, marginal-marine sands and silts were deposited closer to the shoreline. Interdigitation between the dark mudstone and the marginal-marine deposits is apparent. The known depositional area was inundated with marginal-marine deposits in the middle Senonian (Santonian). This marginal-marine deposition continued into the lower Tertiary, without apparent break. In some sections, 2,000 ft of sediment is barren of fauna between the Upper Cretaceous (Santonian) and Lower Tertiary (Paleocene and lower Eocene) faunas. All the marine and marginal-marine Upper Cretaceous sediments are regarded as being of paralic origin.

The structural configuration of the unconformably underlying Otway Group controlled the transgressive Upper Cretaceous sedimentation. Faulting and warping initiated Upper Cretaceous sedimentation and continued contemporaneously with it and Lower Tertiary sedimentation.

53 species of Foraminifera are described and illustrated. The following new species are erected: *Allomorplina pyriformis*, *Ceratobulimina kremnoides*, *Colomia austrotrachus*, *Gyroidinoides cruachin*, *Pallaimorphina heliciformis* and *Textularia trilobita*.

### Introduction

No Cretaceous sediments were recognized in Victoria until 10 years ago when Kenley and others collected angiosperm leaves from the Runnymede Formation (highest unit of the Mesozoic Merino Group of the Casterton area—Kenley 1954). Baker and Cookson (1955) reported the presence of Upper Cretaceous microplankton from the 'Nelson Bore' (Glenclg No. 1—near the South Australian border). Further palynological work led Cookson (in Cookson & Dettmann 1958) to believe that the non-marine Mesozoic sediments, outcropping in W. Victoria, were of Lower Cretaceous age. These rocks had always been regarded as Jurassic in age.

No Mesozoic marine faunas had been found until the Victorian Mines Department drilled the Belfast No. 4 Bore at Port Fairy. From this bore, a core contained a molluscan fauna which was recognized by Kenley (1959) as being of Upper Cretaceous age. 10 subsequent bores have penetrated marine or marginal marine Cretaceous sediments at depth below 2,000 ft. Douglas (1960) and Cookson &

Eisenack (1961) have studied the microplankton content in the Upper Cretaceous sediments from some of these bores.

This study is based on the distribution of Upper Cretaceous Foraminifera in all bores drilled in W. Victoria. The results are divided into two parts. Part A deals with the depositional history of the sediments which contain Upper Cretaceous Foraminifera, while in Part B the species of Foraminifera are described.

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### Localities and Sampling Methods

Marine Cretaceous sediments occur at depth along the coastal strip in W. Victoria extending from Port Campbell W. to Portland (see Fig. 1) which is within the Portland Sunkland as defined by Boutakoff (1952). The marine Cretaceous has not been reported more than 10 miles inland from the present coastline and is not recorded at less than 2,000 ft below sea level.

There is only one reported occurrence of the Victorian marine Cretaceous W. of Portland. This is in the 'Nelson Bore' (Glenelg No. 1). The 'Nelson Bore' has not been examined by the author as it is felt that the little remaining material from this bore should be preserved, especially as Crespín (1954) found no Cretaceous Foraminifera in the samples. Other aspects of the 'Nelson Bore' sediments have been published (Baker & Cookson 1955, Douglas 1960, Baker 1961).

The bores examined are those drilled in the Western District Basin before May 1963.

The bores are tabulated and positioned on Fig. 1. The term 'well' implies drilling in search of petroleum, while the term 'bore' is used for all other drilling. The plural 'bores', without geographic prefixes, is used collectively implying all bores and wells mentioned. Unless specified, all depths mentioned are 'drilled depth'

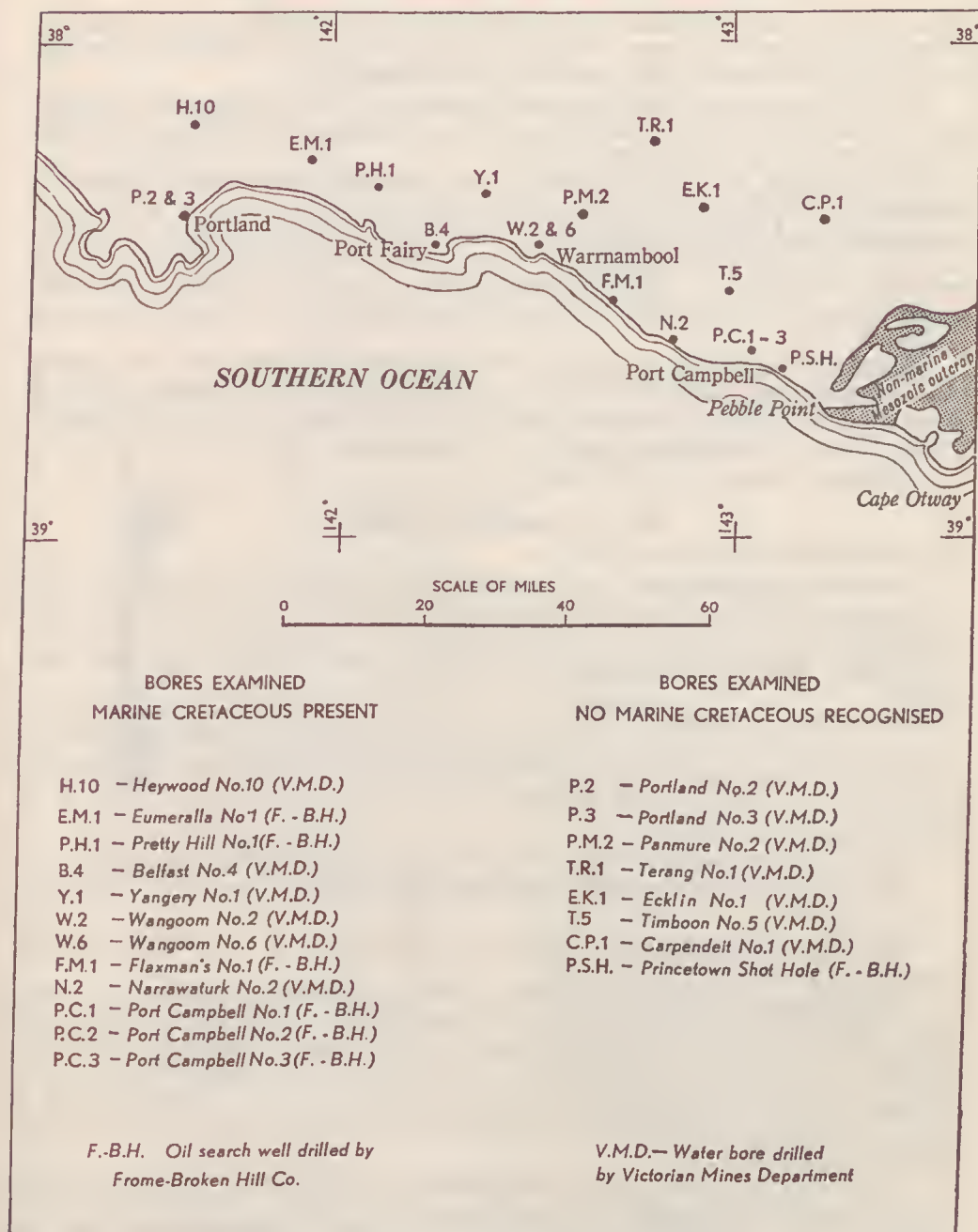


FIG. 1—Bore locality map W. Victorian coast.



which have not been adjusted to sea level. Ground level is the datum taken in Mines Department water bores, while the height of the Kelly bushing (above sea-level) is taken as datum in the Frome-Broken Hill wells.

The limiting factors in this study were the position of bores, rig capacity, coring interval and rotary cutting contamination. Economic factors dictated the positions of bores and did not lead to pattern drilling.

Port Campbell No. 2 is established as the standard section of the Cretaceous foraminiferal sequence as is known at present in Victoria. This is because the samples provided adequate information, the sequence is at its thickest (2,600 ft), and there is no facies interfingering to interfere with foraminiferal distribution. The well was 'side-tracked' at 5,600 ft giving another section below 7,000 ft with better samples than those of the 'first cut' hole. Information from both holes have been combined.

Because of difficulties in preparing the indurated mudstones and the varying amounts of samples available, it was not possible to prepare a constant amount of each sample. Therefore, in order to ascertain relative frequencies of species present, 5 trays (9 cm  $\times$  5 cm), single spread with residue, were picked. Selective picking was conducted on any remaining residue.

### Part A: Depositional History

#### ROCK STRATIGRAPHY

The non-marine Mesozoic rocks outcrop in the Western District Basin, on the E. margin in the Otway Ra., and on the NW. margin in the Casterton area. The remaining area is covered by Tertiary sediments which are concealed, in part, under late Tertiary to Quaternary basalts and along the coast by Quaternary dune limestones.

The Tertiary sequence is exposed on the E. margin of the area, where 2,790 ft of sediments were measured by Baker (1950, p. 29) along the coast between Pebble Point and Princetown. This section shows an almost complete sequence from the Paleocene to at least middle Miocene. Two broad lithological units can be subdivided in this sequence:

- (i) The higher predominantly calcareous unit—The Heytesbury Group.
- (ii) The lower predominantly arenaceous and argillaceous unit—The Wangerrip Group.

These units are proposed by Baker (1953, p. 126), who also suggests there is a transitional unit between the two.

The Wangerrip Group is apparently of paralic origin with distinct marine incursions. The Pebble Point Formation is the basal member of the Group and consists of conglomerates and grits with some mud lenses. Above the base of the Formation the grits are fossiliferous (Mollusca and Foraminifera), marking the Paleocene marine transgression mentioned by Glaessner (1959, p. 61). A littoral origin is indicated which may account for the difficulty of recognizing this Formation away from the marginal area.

In outcrop, the Pebble Point Formation rests unconformably on the felspathic sandstones of the Mesozoic Otway Group. However, deep drilling in the Port Campbell area has revealed sediments between the Wangerrip Group and the Otway Group. These sediments have been divided into four units by Bain & McQueen (in press), whose formal definitions are summarized in Fig. 2 in this paper. (A summary is given in McQueen 1961.)

As seen in Fig. 2, the Cretaceous Foraminifera are restricted to the Belfast



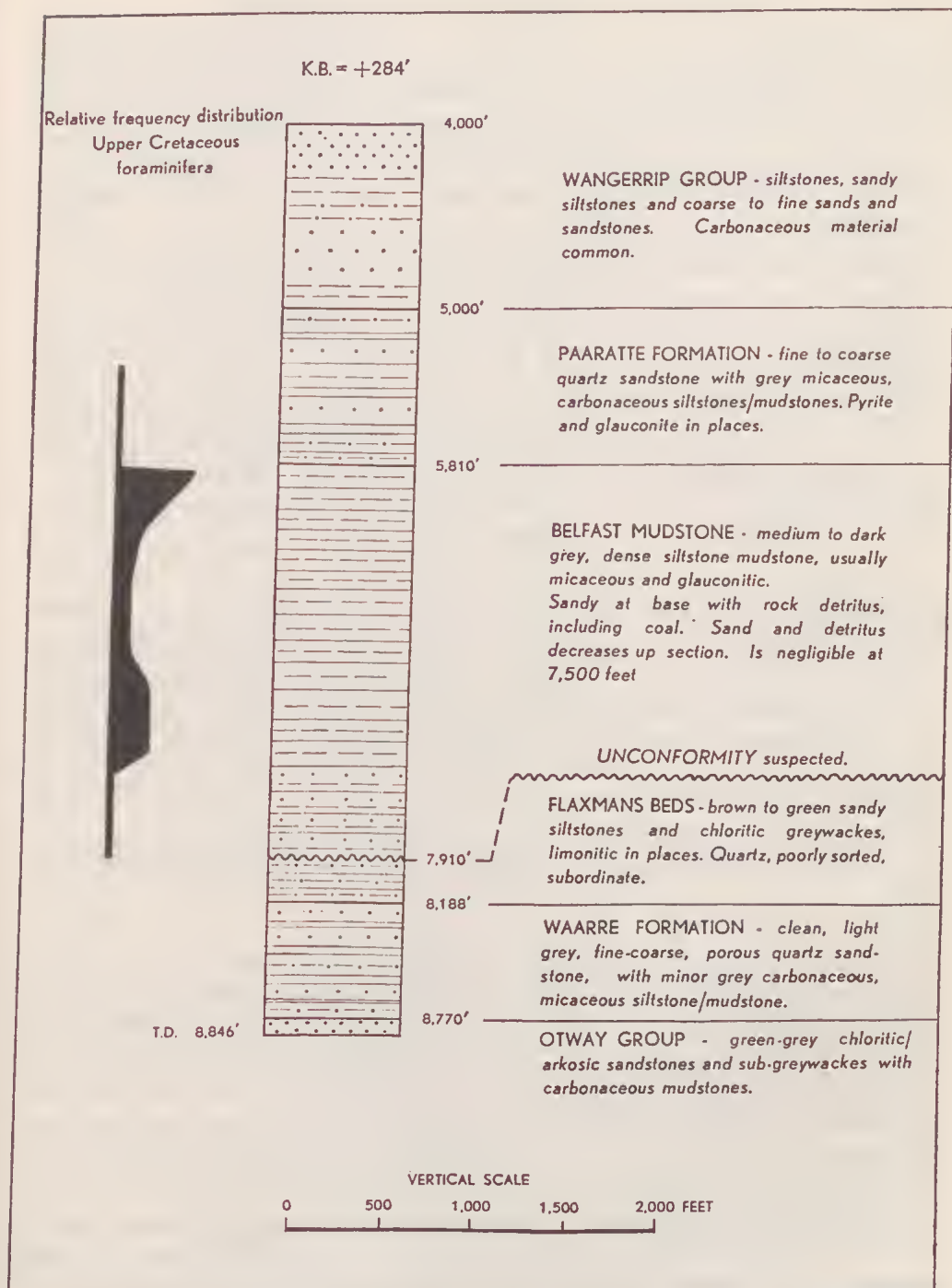


FIG. 2—Rock-stratigraphic column, Port Campbell No. 2 Well.

Mudstone and the Paaratte Formation in the Port Campbell No. 2 section. The frequency diagram in the figure indicates that the Foraminifera are most abundant at the top of the Belfast Mudstone, but rare at the base and also rare in the Paaratte Formation. Although there is a report of Foraminifera below the Belfast Mudstone, the author has not observed any, despite the examination of numerous samples.

The base of the Waarre Formation intergrades with the Otway Group and is considered to be a formation within this group. Although there appear to be disconformities within and at the top of the Flaxmans Beds, it may be best to consider this unit as the result of weathering contemporaneous with the exposure of the older sediments (Otway Group). This marks the beginning of a new cycle of sedimentation which led to the subsequent deposition of the Belfast Mudstone.

There is no evidence of an unconformity between the Belfast Mudstone and the Paaratte Formation. In fact, the upper horizons of the Belfast Mudstone in Port Campbell No. 2 are synchronous with the basal horizons of the Paaratte Formation in other sections (e.g. Port Campbell No. 1 and Flaxmans No. 1). The Paaratte Formation may contain sediments lithologically and palaeontologically similar to the Belfast Mudstone, but separated from it by sandstones and sandy siltstones.

There is no apparent depositional break between the Paaratte Formation and the overlying Wangerrip Group and the lithological break between these units is hardly clear cut. The Cretaceous foraminiferal sequence extends into what is considered as Wangerrip Group in Flaxmans No. 1 Well.

Little is known of the marine Cretaceous sediments W. of Port Fairy. Portland No. 2 and 3 bores ceased drilling while still in Tertiary rocks. Heywood No. 10, Eumeralla No. 1, and Pretty Hill No. 1 revealed thin developments of sediments analagous with the Paaratte Formation and Belfast Mudstone. The sub-surface Tertiary stratigraphy of the Portland area is discussed by Glenie and Reed (1960). To the N. of Portland, the non-marine Mesozoic Merino Group sediments are unconformably overlain by the Bahgallah Formation (Kenley 1951) in the Casterton area. The Bahgallah Formation is similar in lithology and fauna to the Pebble Point Formation. As the Merino Group is equated with the Otway Group, the situation on the exposed NW. margin is identical with that on the E. margin of the basin.

A reappraisal of the Victorian Cretaceous rock stratigraphy is attempted in a later section. This is felt necessary as a result of evidence accumulated in this study.

#### BIOSTRATIGRAPHY

##### (a) The fauna

As first reported by Kenley (1959), the Cretaceous marine fauna consists of representatives of the following Groups: Foraminifera, Pelecypoda (*Inoceramus* sp. absent), Schaphopoda, Gastropoda, Pteropoda (?), Ammonoidea, rotularid worm tubes, Echinoidea (plates), and fish remains. This fauna was found near the top of the Belfast Mudstone in Belfast No. 4 Bore between 4649 ft and 4655 ft (cored interval). Even though Cretaceous fossils have been found in 11 other bores, this broad faunal list has not been greatly expanded. Notable additions are 4 species of Ostracoda in many samples, belemnite fragments, *Inoceramus* shell fragments near the base of the Belfast Mudstone, and moulds of a different species of *Inoceramus* in the Paaratte Formation.

Foraminifera are the most abundant, widespread, and specifically diverse element of the fauna. Macro-fossils are sparse within the sequence, but their observation depends on the chance factor of coring. It would appear that the macro-faunas (especially mollusca) are congregated at certain horizons near the top of the Belfast

Mudstone. The exception is *Inoceramus*, which is most abundant in the lower horizons of the Belfast Mudstone.

Arenaceous forams are dominant within the foraminiferal fauna. Calcareous Foraminifera are restricted in distribution and never comprise more than 30% of the total fauna in any one sample. The planktonic foraminiferal fauna is neither specifically rich, nor distributed throughout the sequence.

The Belfast No. 4 core, at 4649 to 4655 ft, contains a rich foraminiferal fauna with species typical of the upper part of the Belfast Mudstone. This fauna is listed below:

Arenaceous Foraminifera: *Amniobaculites* cf. *fragmentaria*, *Dorothia filiformis*, *Haplophragmoides* spp. (3 species), *Hyperammina elongata*, *Marssonella oxycona*, *Reophax* sp., *Textularia anceps*, and *T. semicomplanata*.

Calcareous Foraminifera: *Alabamina australis*, *Buliminella* cf. *parvula*, *Ceratobulimina kremnoides*, *Cibicides excavatus*, *C. ribbingi*, *Frondicularia* sp., *Globulina lacrima*, *Gyroidinoides cruachin*, *G. nitida*, *Hanzawaia californica*, *Hoeglundina subcretacea*, *Lenticulina* spp., *Marginulina inaequalis*, *Nodosaria obscura*, *N. navarroana*, *Pallaimorphina heliciformis*, *Praebulimina ovulum*, *Quinqueloculina* sp., *Stilostomella alexanderi*, *Valvulineria undulata*, *V. erugata*.

Planktonic Foraminifera: *Guembelina reusii* and *Hedbergella trochoidea*.

The lower levels of the Belfast Mudstone (as present in Port Campbell No. 2) contain some of the above species, together with such restricted species as *Colomia austrotrochus*, *Gavelinopsis cenomanica*, and *Textularia trilobita*.

#### (b) The faunal sequence

The outstanding feature of the Victorian Cretaceous foraminiferal sequence is the alternation of predominantly arenaceous assemblages of Foraminifera with mixed arenaceous/calcareous assemblages. The Cretaceous faunal distribution chart for Port Campbell No. 2 Well (Fig. 3) shows 3 horizons marked by arenaceous faunas and 2 horizons of mixed arenaceous/calcareous faunas.

The faunal distribution in Port Campbell No. 2 would appear to be the basis of a biostratigraphic sequence. The horizons within the sequence are defined on the presence or absence of selected species, and not on evolutionary changes within one or few genera. The main correlatable features are the horizons of extinction of selected species. Glaessner (1955, p. 6) suggests that 'the theoretical basis for this procedure which results from the preoccupation of practical stratigraphic micropalaeontology with bore material, is not clear'. The difficulties in applying this procedure are mainly due to facies changes. A facies change may result in the extinction of certain species in a sequence. One must consider whether this facies change happens on the same time-plane throughout the area under study. E.g., in the Port Campbell No. 2 sequence, one must consider if the faunal changes between Assemblage 2 and Assemblage 1 were due to the vertical facies change that is expressed in the change from black mudstone to silty and sandy sediments. Later in this text, it will be shown that the faunal differences between Assemblage 2 and Assemblage 1 are, in fact, a facies change and it is believed that this facies change did not take place on the one time-plane through the area.

Therefore, it is necessary to assess the faunal changes in the Port Campbell sequence in order to see if they can be reliably correlated throughout the area of study. Faunal changes which are involved with facies changes will be mentioned, but will be dealt with fully in the section on depositional environment which appears later.

No calcareous species are constantly present throughout the sequence. Mainly



AGE	Uppermost Cretaceous	SANTONIAN						TURONIAN			Lower Cretaceous
BIOSTRATIGRAPHIC UNITS		ZONULE A						ZONULE B			
FAUNAL ASSEMBLAGES	No fauna	ASSEMBLAGE 1	ASSEMBLAGE 2	ASSEMBLAGE 3	ASSEMBLAGE 4	ASSEMBLAGE 5	No fauna	No fauna	No fauna	No fauna	
DEPTH SAMPLE POSITION	5,000	142	3		12	4	13	5			
FAUNAL LIST		5,300	5,900	6,300	7,000	7,440	7,904	8,104			
<b>ARENACEOUS FORAMINIFERA</b>											
<i>Haplophragmoides</i> sp. A.		x x x x x	x o o o x x x x x x x		x						
H. sp. B.		" "	x o x		x						
H. sp. C.		" "	x o x		x						
<i>Bathysiphon</i> sp.		x	x x x x x	x x x x x	x						
<i>Marssonella oxycona</i>		x	x o x x x x	x x	x						
<i>Ammobaculites subcretacea</i>		"	x		x						
A. goodlandensis		"	x		x						
A. cl. fragmentaria		x x	x		x						
<i>Dorothyia liliformis</i>		x x	x	x x x x x x x x x x	x x x	x x x					
<i>Hyperammina elongata</i>			x								
<i>Ammodiscus</i> sp.			" x		"						
<i>Textularia anceps</i>			x x x x		x						
T. semicomplanata			x x x x	x	" x						
T. trilobita											
<b>CALCAREOUS FORAMINIFERA</b>											
<i>Alabamina australis</i>		" "	x	x	x						
<i>Quinqueloculina</i> sp.		"	x		"						
<i>Marginulinopsis curvisepia</i>		" "	" x								
<i>Robulus</i> sp.		"									
<i>Hoeglundina subcretacea</i>		"									
<i>Allomorphina pyritiformis</i>			x								
<i>Caratolbulimina kremnoides</i>			x	"							
<i>Cibicides excavatus</i>			x								
<i>Citharina geisendorferi</i>			x								
C. whangana			"								
<i>Cornuspira involvens</i>			x								
<i>Dentalina</i> cl. <i>intrasagma</i>			x								
D. spp.			x								
<i>Gavelinopsis</i> cl. <i>eriksdalensis</i>			x								
<i>Globulina lacrima</i>			x								
<i>Gyrogonoides nitida</i>			x								
G. cruechii			x								
<i>Hanzawaia californica</i>			x								
<i>Lagana</i> spp.			x								
<i>Lenticulina</i> spp.			x								
<i>Robulus navarroensis</i>			x								
<i>Marginulina inaequalis</i>			x								
<i>Nodosaria alternistrata</i>			x								
N. navarroana			x								
N. obscura			x								
<i>Pleurostomella subnodose</i>			x								
<i>Praebulimina ovulum</i>			x								
<i>Fronducularia</i> cl. <i>mucronata</i>			x								
<i>Pseudoglandulina</i> sp.			x								
<i>Colomia austrotrichus</i>											
<i>Gavelinopsis cenomanica</i>											
G. sp?											
<i>Marginulinopsis jarvisi</i>											
<i>Pallaimorphina heliciformis</i>											
<b>PLANKTONIC FORAMINIFERA</b>											
<i>Guembelina reussi</i>			x								
<i>Hastigerinella?</i> sp.			x								
<i>Hedbergella trochoidea</i>			x								
FAUNAL LIST		5,300	5,900	6,300	7,000	7,440	7,904	8,104			
SAMPLE POSITION	5,000	142	3		12	4	13	5			
DEPTH	5,000										
FAUNAL ASSEMBLAGES	No fauna	ASSEMBLAGE 1	ASSEMBLAGE 2	ASSEMBLAGE 3	ASSEMBLAGE 4	ASSEMBLAGE 5	No fauna	No fauna	No fauna	No fauna	
BIOSTRATIGRAPHIC UNITS		ZONULE A						ZONULE B			
AGE	Uppermost Cretaceous	SANTONIAN						TURONIAN			Lower Cretaceous

Frequency symbols - • 1 specimen; x 2-10 specimens; o > 11 specimens. Sample symbols - r rotary cuttings, 10 ft. intervals; \* Core No. 3.  
Drilling information: Datum (Kelly Bushing) +284 feet Total Depth 8,864 feet (Otway Group)  
Hole diverted and recut from 5,650 feet 9 5/8" casing set at 5,650 feet; 5 1/2" casing set at 8,846 feet.

FIG. 3—Faunal distribution chart, Cretaceous section, Port Campbell No. 2.

they appear in 'waves'. No doubt these appearances indicate that environmental conditions were suitable and that chances of preservation were not limited. The presence of a calcareous 'wave' has facies implications. Thus a 'wave' in one bore may not be the exact biostratigraphic correlate of an horizon containing the same 'wave' in another bore.

Some calcareous species occur in all waves in the section, e.g. *Alabama australis* and *Gyroidinoides nitida*. This suggests that the restocking of the fauna with calcareous species was the result of immigrations (or 'waves') which originated from the same source area. For the purpose of biostratigraphy, we must then postulate a 'source section' and assume that this 'source section' was deposited throughout a period (= the depositional period of the Port Campbell No. 2 section) when conditions were suitable for many genera of calcareous Foraminifera.

If a species is restricted to a particular 'wave' in a known section, then this species probably has a restricted range in the 'source section'. As this species is absent from all other 'waves' in the known section, then it is probably absent from equivalent horizons in the 'source section'. However, the full range of this species in the 'source section' may include horizons in the known section which do not contain calcareous species.

It is assumed that this principle can only be applied for species whose appearances are not dictated by ecological factors other than those affecting the 'wave' as a whole. Planktonic species are limited to one sample in the section, which suggests they mark a sudden entry of off-shore currents. Thus, planktonic species have no biostratigraphic significance in the section.

The distribution of calcareous species has biostratigraphic limitations in the sequence because the complete range of any species is uncertain. However, the presence of certain calcareous species can be used in identifying a horizon, but the absence of calcareous species cannot be used as a criterion; thus Assemblage 2 cannot be distinguished from Assemblage 3 for the purposes of correlation.

Further critical examination of the faunal distribution shows that the arenaceous fauna of Assemblage 1 is similar to those of Assemblages 2 and 3 except that *Textularia anceps* and *T. semicomplanata* are absent from Assemblage 1. Assemblage 1 is within the *Paaratte Formation* which resembles a shallow water deposit. Palaeoecological studies (Burnaby 1962; Jefferies 1962) conclude that *Textularia* shows a preference for relatively deep water. Therefore, the faunal differences between Assemblages 1, 2 and 3 are due to environmental factors and are not reliable criteria for correlation. Similarly, the faunal differences between Assemblages 4 and 5 are ecological.

#### (c) The biostratigraphic units

In the Port Campbell No. 2 section the sequence of assemblages may be expressed as follows:

Association =	Assemblage
HA	1
HA + (T + C)	2
HA + (T)	3
ha + (t + c)	4
ha	5

Where HA = *Haplogragnoides* sp. A, H. sp. B, H. sp. C, *Ammobaculites* cf. *fragmentaria*, *A. goodlandensis*, & *A. subcretacea*;

T = *Textularia anceps* & *T. semicomplanata*;

- C** = *Cibicides excavatus*, *Hanzawaia californica*, & *Gyroidinoides cruachin*;  
**ha** = *H. sp. B* & *Ammobaculites goodlandensis*;  
**t** = *Textularia trilobita*;  
**c** = *Colomia austrotrachus* & *Gavelinopsis cenomanica*.

As the distribution of *Textularia* and calareous species appear to be ecologically controlled, the sequence of 5 assemblages is a facies sequence rather than a biostratigraphic sequence. Therefore, an assemblage may not identify the one horizon throughout its lateral extent, even in the Port Campbell area. But a combination of the assemblages forms more reliable units for correlation. Thus:

Unit A (assemblages 1, 2, & 3) may comprise—

Association **HA** : or Association **HA** + (**T**) : or

Association **HA** + (**T** + **C**);

and

Unit B (assemblages 4 & 5) may comprise—

Association **ha** : or Association **ha** + (**t**) : or

Association **ha** + (**t** + **c**).

Obviously Association **HA** is the basic association of Unit A. Likewise Association **ha** is the basic association of Unit B. The auxiliary associations **T** & **C** or **t** & **c** help establish the entity of the unit, for, though they are facies faunas, the ranges of **T** & **C** do not overlap with those of **t** & **c**. E.g., the range of *Textularia trilobita* does not overlap that of *T. anceps* and *T. semicomplanata*. The replacement of the former by the latter 2 species marks the boundary between Unit B and Unit A.

These faunal units are established so that the sediments which contain them in one bore can be recognized in other bores, no matter what lateral facies changes occur. Of course the limitation is the absence of Foraminifera and the recognition of arenaceous species which are simple in structure, thus flexible in specific character in areal distribution.

As these units distinguish one group of sediments from another on faunal criteria they are biostratigraphic units.

The units are localized units, thus not biostratigraphic zones which Oppel defines as 'Palaeontologically identifiable complexes of strata' (in Teichert 1958a, p. 109). Teichert furthers this definition by stating that a zone is 'a bed or beds characterized by one or more than one fossil species or genera, used for intercontinental or world-wide correlation'.

The world-wide foraminiferal zonation of the Upper Cretaceous is based on the vertical distribution of certain genera, such as *Globotruncana*, which are absent throughout the Victorian sediments. (Proof of the Upper Cretaceous age will be given later.) Within the Victorian sequence there are species which have worldwide range, but their biostratigraphic ranges are either vague or cover more than one *Globotruncana* zone. No other fauna present is of value in zonation.

The term 'zonule' is an adequate one for the two biostratigraphic units in the sequence. Fenton & Fenton (1928) proposed the term zonule as 'the strata or stratum which contains a faunule, its thickness and area being limited by the horizontal and vertical range of that faunule'. Kleinpell (1938) more precisely defines a zonule as a 'locally recognizable biostratigraphic unit'.

Fenton & Fenton's definition of a zonule employs the term faunule which they define as 'an assemblage of fossil animals associated in one or few contiguous strata and dominated by one community, commonly either an association or a layer



society'. The 3 assemblages which comprise Zonule A (Unit A) cannot be regarded as faunules, but the combined assemblages are a faunule as they are dominated by the Association HA. Likewise, Assemblages 4 & 5 combine to form Zonule B. The individual assemblages have been dismissed for biostratigraphic correlation because of their facies implications. However, they will be used in illustrating the changes in depositional environment both laterally and vertically throughout the area.

(d) Correlation of biostratigraphic units

Table 1 lists the vertical distribution of the biostratigraphic units in each Cretaceous foraminiferal sequence examined. The bores are arranged in order of distance W. of Port Campbell No. 2.

TABLE 1

Bores	Depths of Zonules (ft)		Unit at Base	Distance from Port Campbell No. 2 (miles)
	A	B		
Port Campbell No. 2	5016 to 5716	6716 to 7620	Flaxmans Beds	—
Port Campbell No. 1	3902 to 5002	5002 to 5308	Waarre Form	1.8
Port Campbell No. 3	3878 to 4448	Absent	Waarre Form	4.6
Narrawaturk No. 2	4858 to 5498	?	—	6
		(Total depth)		
Flaxmans No. 1	3777 to 6077	6077 to 6437	Flaxmans Beds	13
Wangoom No. 6	2873 to 3277	Absent	Otway Group	31
Yangery No. 1	2435 to 2658	Absent	Otway Group	40
Belfast No. 4	24300 to 5279	Absent	Otway Group	44
Pretty Hill No. 1	2180 to 2647	Absent	Flaxmans Beds	55
Eumeralla No. 1	2572 to 2940	Absent	Otway Group	70
Heywood No. 10	4800 to 5298	?	—	81
		(Total depth)		

N.B. All depths adjusted to sea level.

The biostratigraphic correlations are illustrated on the panel diagram of Fig. 6. The faunal distribution charts for Flaxmans No. 1 and Port Campbell No. 1 (not included in this paper) show that the diagnostic species are distributed so that it is possible to recognize the 2 Zonules of the Port Campbell No. 2 sequence. The gross faunal content is much the same in each of the 2 faunules in all 3 wells. The main additions to the fauna are the presence of *Valvulineria erugata* and *V. lenticula*, both restricted to Zonule A, appearing in the calcareous 'waves'.

The Cretaceous foraminiferal sequence reaches a maximum thickness of 2600 ft in Port Campbell No. 2 and Flaxmans No. 1, but sediments containing the 2 Zonules vary in thickness between the 2 bores. In Flaxmans, Zonule A is 600 ft thicker while Zonule B is 550 ft thinner. Between Port Campbell No. 2 and Flaxmans there is little biostratigraphic information, as Narrawaturk ceased drilling while still in Zonule A.

Both Zonules can be recognized in Port Campbell No. 1 but there is considerable thinning of sediments over the 1.8 miles from Port Campbell No. 2.

The sequence is only 560 ft thick in Port Campbell No. 3 and Zonule B is absent. Zonule B is absent from all other bores listed, in fact its distribution is restricted to a narrow coastal belt between Port Campbell and Flaxman's Hill. Marine Cretaceous sedimentation would appear to have initiated in this belt.

The top of the Cretaceous foraminiferal sequence does not coincide with the

SPECIES	Albian	Cenomanian	Turonian	Coniacian	Santonian	Campanian	Maastrichtian	Danian	Victorian biostrat. ranges Zonules	
									A	B
<i>Alabamina australis</i>									x	x
<i>Ammobaculites fragmentaria</i>	?								x	
<i>A. goodlandensis</i>									x	x
<i>A. subcretacea</i>									x	
<i>Buliminella parvula</i>									x	
<i>Ceratobulimina cretacea</i>									x	
<i>Cibicides excavatus</i>				- ? -		- ? -			x	
<i>C. ribbingi</i>									x	
<i>Citharina geisendoerferi</i>				- ? -					x	
<i>C. whangaia</i>									x	
<i>Cornuspira involvens</i>									x	
<i>C. subprimitiva</i>									x	
<i>Dentalina intrasegma</i>									x	
<i>Dorothia conulus</i>									x	
<i>D. filiformis</i>				?					x	x
<i>Fronicularia mucronata</i>									x	
<i>Gavelinopsis cenomanica</i>										x
<i>G. eriksdalensis</i>									x	
<i>Globulina lacrima</i>									x	x
<i>Guembelina reussi</i>									x	
<i>Gyroidinoides nitida</i>									x	x
<i>Hanzawaia californica</i>									x	
<i>Hedbergella trocoidea</i>				- ? -					x	?
<i>Hoeglundina supracretacea</i>									x	x
<i>L. (Marginulinopsis) jarvisi</i>										x
<i>L. (Marginulinopsis) curvisepata</i>			- ? -	- ? -	- ? -	- ? -			x	x
<i>L. (Robulus) navarroensis</i>									x	x
<i>Marginulina inaequalis</i>									x	
<i>Marssonella oxycona</i>									x	x
<i>Nodosaria obscurra</i>									x	x
<i>N. alternistriata</i>									x	x
<i>N. navarroana</i>									x	
<i>Pleurostomella subnodosa</i>									x	
<i>Praebulimina ovulum</i>									x	
<i>Stilostomella alexanderi</i>									x	
<i>Textularia anceps</i>									x	
<i>T. semicomplanata</i>									x	
<i>Valvulineria erugata</i>									x	
<i>V. lenticula</i>									x	
<i>V. undulata</i>									x	

FIG. 4.—Documented time ranges of foraminifera described from Victorian Cretaceous.

base of the Tertiary foraminiferal sequence in any bore section. There is more than 2000 ft of sediment barren of Foraminifera, between the last occurrence of Cretaceous forms and the first occurrence of Tertiary forms, in Narrawaturk No. 2. This barren interval is only 400 ft thick in the Warrnambool area. Sedimentation (non-marine) appears to be continuous between the marine Upper Cretaceous and the marine lower Tertiary.

In Timboon No. 5 and Wangoom No. 2, no Cretaceous Foraminifera were found in the 500 ft (approx.) interval between the early Tertiary marine sediments and the Otway Group. Biostratigraphic correlation of these 2 bores is therefore impossible, although it is extremely doubtful if any of this sediment is the equivalent of Zonule B. An ammonite fragment found in a core at 3106 ft in Wangoom No. 2 is of no biostratigraphic value as it is probably derived, being badly worn.

#### TIME STRATIGRAPHY

Fig. 4 is a tabulation of the time distribution of all described species from the Victorian Cretaceous foraminiferal sequence. The European stage classification of the Cretaceous by Muller & Schenck (1943) is followed. The time ranges of the species are those given by the authors listed in the synonymy included with each specific description (Part B of this text).

The reported ranges of 40 species are tabulated. All but 2 species have been recorded from the Upper Cretaceous and 29 species have been recorded only from the Upper Cretaceous. 20 of the species are restricted to beds of Senonian age, while the Senonian is within the range of 12 other species.

A comparative age determination only can be reached as species with precise vertical ranges are absent (e.g. *Globotruncana* spp.). A summation of reported ranges of species suggests a Senonian age. The entire Victorian fauna must then be compared with a well documented Senonian fauna close at hand. Such faunas are discussed and partially monographed by Belford (1958 & 1960) from Western Australia. Belford assigns these faunas to the Santonian and Campanian. The Santonian age is established on erinoid plates of the genus *Marsupites*, which is a zone fossil of the European section. Also the Western Australian Senonian microfaunas contain *Globotruncana* spp. Neither upper Turonian nor Coniacian faunas have been recognized from Western Australia. On this evidence, Belford (1958, p. 637, Fig. 9) infers that a general regression commenced, probably in the lower Turonian, and that deposition was resumed in the Santonian.

The following species occur in the Victorian sequence and are listed by Belford (loc. cit.) as being restricted to the Santonian Gingin Chalk and the Santonian-lower Campanian Toolonga Calcilutite: *Alabamina australis*, *Cibicides excavatus*, *C. ribbingi*, *Citharina geisendoerferi*, *Nodosaria obscura*, *Pleurostomella subnodosa*, *Praebulimina ovulum*, *Valvulineria erugata*, *V. lenticula*, & *V. undulata*. Belford also lists *Fronicularia mucronata* and *Gavelinopsis eriksdalensis*, which are not positively identified in the Victorian sequence. *A. australis*, *V. undulata*, and *V. erugata* were first described by Belford (1960) and have only been reported by him. The first 2 species are restricted to the Santonian beds, while the third species extends into the lower Campanian. As the Coniacian and upper Turonian faunas are not known in Western Australia, the ranges of these 3 species could well extend from the upper Turonian. The species listed from Western Australia are not all restricted to the Santonian-lower Campanian outside Australia, but their tabulated ranges overlap in the Santonian.

These species listed from Western Australia are reported mainly from Zonule A,



the upper zonule, of the Victorian sequence. Other species recorded only from Zonule A do not contradict a Santonian age. Purely Campanian and Maastrichtian species have ranges which are not well documented (e.g. *Hanzawaia californica* and *Ceratobulimina cretacea*). The pre-Santonian ranges of listed species of *Anmoba-*  
*lites* and *Cornuspira* are dismissed because a simplicity of structure. The full range of *Dorothia filiformis* is difficult to ascertain and may range into the Senonian, and the determination of *Hedbergella trocoidea* is a generic rather than specific determination and thus is of no stratigraphic value. Thus, the species present suggest a Santonian age for the sediments of Zonule A of the Victorian sequence.

*Gavelinopsis cenomanica* is restricted to Zonule B of the Victorian sequence and this species has an established range of upper Albian into Turonian in Europe. Of the other species restricted to Zonule B, *Textularia trilobita* and *Colomia austro-*  
*trochus* are new species, while *L. (Marginulinopsis) jarvisi* is not well documented. Species recorded in this zonule have ranges which include the Turonian, with the exception of species of *Lenticulina* and *Nodosaria*, while *Alabamina australis* could extend into the upper Turonian (see above). Thus, the species present suggest a Tronian age for the sediments of Zonule B.

Some of the new species described in this text are of genera which are of limited vertical distribution elsewhere. The generic ranges of the new species are now discussed, as well as the range of species with affinities to the new species.

*Allomorphina pyriformis:*

This genus is reported from the Coniacian to the Recent. This species has no close affinities with the Cretaceous species of *Allomorphina*, but has close affinities with the Paleocene forms, *A. halli* Jennings and *A. paleocenica* Cushman.

*Ceratobulimina kremnoides:*

The generic range extends from the upper Albian to the Recent. This species has no close affinities with the Cretaceous species of *Ceratobulimina*, but has close affinities with the Paleocene form *C. westraliensis* Parr which occurs in the Pebble Point Formation which overlies the Victorian Cretaceous sediments.

*Colomia austrotrochus:*

This genus is represented by 3 species, 2 occur in the Maastrichtian while the third occurs in the Campanian. This species may be a more 'primitive' member of the Genus *Colomia* (see specific description later).

*Gyroidinoides cruachin:*

The genus is a long ranging one, but the species has affinities with *G. pontoni* Brotzen of the upper Campanian to Paleocene of Europe.

*Pallaimorphina heliciformis:*

This genus is represented by 3 species, two of which occur in the Albian and the third in the Turonian. The Victorian species is distinct. As this genus is of limited occurrence, the generic range could extend upwards.

The reported occurrences of the genera discussed have not altered the age determinations already made. It is interesting that 3 of the new species have affinities with Paleocene species, while a fourth species, *Buliminella* cf. *parvula*, appears to intergrade with the Paleocene species *B. westraliensis* Parr. This could indicate gradual specific transitions between the Santonian and the Paleocene.

The lowest calcareous foraminiferal assemblage is no older than Turonian, while

the higher calcareous assemblages are Senonian and probably no younger than Santonian. Though Zonule B contains species suggesting the Turonian age and Zonule A contains species indicating a Santonian age, it does not follow that each of the 2 Victorian biostratigraphic units represent distinct ages. Calcareous species provide the major evidence for these age determinations. The assemblages containing calcareous species of Zonule A (e.g. Assemblage 2 in Port Campbell No. 2) are not contiguous with the assemblages containing calcareous species of Zonule B (e.g. Assemblage 4 in Port Campbell No. 2). There is always an assemblage of arenaceous species (Assemblage 3 in Port Campbell No. 2) between the two calcareous assemblages. Neither is there any other palaeontological, lithological, or structural evidence of a discontinuity of sedimentation between the two Zonules which would indicate a depositional break between Turonian and Santonian (during the Coniacian).

The outlined evidence implies that sedimentation of the Victorian Upper Cretaceous marine rocks commenced during the Turonian and continued till the Santonian. During or at the end of the Santonian there was a marine regression, though non-marine sedimentation appears to be continuous until the marine transgression in the Paleocene. The marine regression was gradual (see following discussion of depositional environment) and the arenaceous assemblages at the top of the foraminiferal sequence (e.g. Assemblage 1 in Port Campbell No. 2) could be Campanian in age. The uppermost Cretaceous was a period of marine regression from the Australian continental areas (Glaessner 1962, p. 246).

The Santonian age assigned to the upper part of the marine Cretaceous sediments (Zonule A) is in agreement with the Senonian age given by Cookson and Eisenack (1961) for the microplankton in these sediments in the Belfast No. 4 Bore. It is noted that Zonule B is absent in the Belfast No. 4 section. However, a new pollen tetrad, *Amosopollis cruciformis*, is recorded by Cookson and Balme (1962) from levels within Zonule B in Port Campbell No. 1 and No. 2, and Flaxmans No. 1, as well as in sediments below this Zonule. This pollen tetrad was described from the ? Aptian to Cenomanian Osbourne Formation in the Perth Basin (Western Australia). Therefore, it would appear that the Victorian Cretaceous marine sequence can be divided into an older unit and a younger unit on other than foraminiferal evidence.

Dr M. F. Glaessner has examined the Cretaceous faunas in all cores from Port Campbell No. 1, No. 2, No. 3, and Flaxmans No. 1. His report is to be published as an appendix to the completion reports in the forthcoming Commonwealth Petroleum Search Subsidy Acts Publications. Dr Glaessner concludes that the faunal evidence favours a Turonian age, although a Coniacian age is possible for the upper part of the Belfast Mudstone. His evidence is against any upper Senonian being present.

Dr Glaessner comments that 'this fauna includes the previously unknown ancestors of a number of Tertiary foraminifera from Southern Australia'. The author arrived at the same conclusions which are noted above.

#### DEPOSITIONAL ENVIRONMENT

The gross character of the Victorian Cretaceous foraminiferal fauna is not constant throughout any of the thicker sections. The distribution of many of the genera is sporadic and suggests that their presence or absence is dictated by the depositional environment. By an ecological interpretation of both the lithological and palaeontological characters of the rocks, the basic framework of the depositional environment can be postulated.

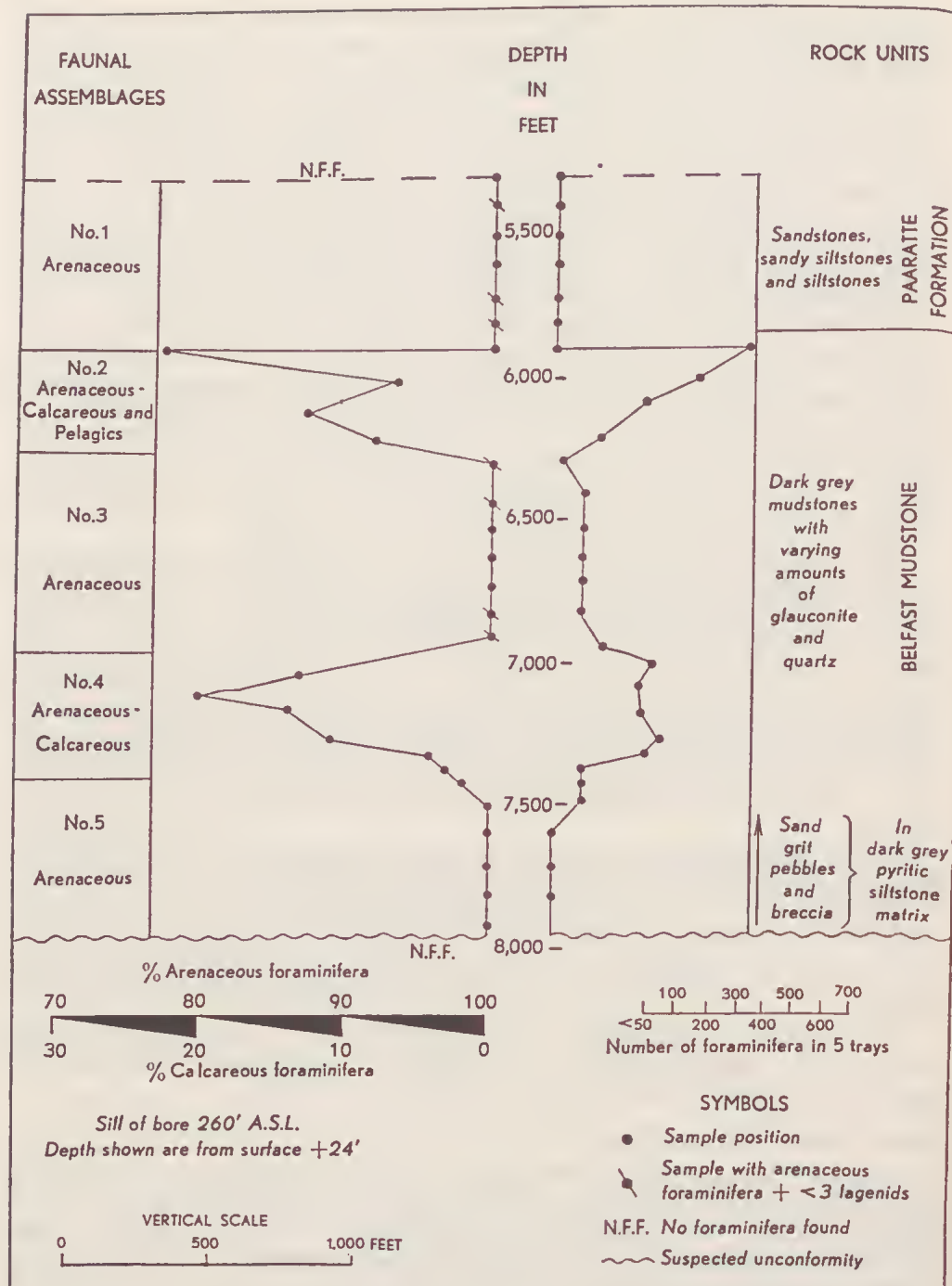


FIG. 5—Variation in gross character and frequency of Cretaceous foraminifera in Port Campbell No. 2 section.



## (a) Palaeoecology

A major palaeoecological character is the alternation of assemblages of arenaceous species with assemblages of associated arenaceous and calcareous species. This alternation of faunas is well illustrated in Fig. 5 where the total number of Foraminifera is plotted against the percentage of calcareous forms. The 2 plots correspond with 5 distinct intervals on each plot. Obviously these 5 intervals represent the 5 faunal assemblages discussed earlier in the text.

The Port Campbell No. 2 section contains a predominantly arenaceous fauna, as the percentage of calcareous forms never exceeds 30% and  $\frac{1}{4}$  of the samples contain less than 5% calcareous forms. Many authors (e.g. Glacssner 1945, p. 100) interpret cold water conditions for the predominance of arenaceous species in a fauna. If cold water conditions are assumed for the whole period of Cretaceous sedimentation, water temperature fluctuations are not reasonable explanations for the appearance of 'waves' of calcareous species in a section. Lowman (1949, p. 1957) states that '*Haplophragmoides*, *Trochammina* and their associates tolerate bottom conditions that normal assemblages will not tolerate'. Such conditions are listed below:

(i) Cushman (1950, p. 44) is of the opinion that arenaceous forms prefer shallow brackish water conditions, while Lowman (loc. cit) shows that living assemblages, dominated by *Haplophragmoides* and *Trochammina*, can be characteristic of brackish marshes. Various authors (e.g. Stelck & Wall 1954, Tappan 1960) have postulated a brackish water origin of certain Turonian sediments which contain purely arenaceous foraminiferal fauna.

(ii) Unsettled benthonic conditions caused by rapid sedimentation and turbidity currents which produce muddied water. According to Stainforth (1952, p. 24) a robust microfauna is typical of a near shore environment of high turbidity.

(iii) Restriction in water circulation resulting in an anaerobic benthonic environment. Baas Becking et al. (1960, p. 259-261) discuss such conditions in the deposition of green and black clays in a neritic environment. Calcareous forms could not tolerate such environments, especially as bacterial activity can release  $H_2S$ . Any test transported into such an environment probably would be dissolved, particularly if they are perforate forms (e.g. planktonic species). Such conditions exist at present in Toyama Bay (Japan) and arenaceous forms are the only Foraminifera living in this environment (summarized by Takayanagi 1960, p. 59). Similarly, in the Gulf Coast, marine environments with low oxygen content are dominated by arenaceous forms (Lowman loc. cit.).

(iv) Extremely deep water, by tolerance to low temperature and low oxygen content.

A series of environmental events can be deduced for the Port Campbell No. 2 section, purely on the alternation of the faunal assemblages. These assumptions are discussed in ascending order.

**Assemblage 5** appears at a definite marine transgression with the deposition of unsorted detrital material. Total number of Foraminifera gradually increases with the decrease in grain size and amount of detritus. The nature of the sediments suggests muddy, turbid water conditions, thus explaining the absence of calcareous Foraminifera.

**Assemblage 4** is in black mudstone. Sedimentation would have been slow as the sediment is extremely fine-grained and glauconite was forming. The total number of Foraminifera increases and calcareous species appear.

**Assemblage 3** is in the same kind of sediment as Assemblage 4, although the amount of glauconite increases. Anaerobic conditions are suggested for this interval to account for little lithological change, yet the absence of calcareous Foraminifera. Restricted water circulation would influence the benthonic environment in such a manner.

**Assemblage 2** is still within the black mudstones. There is a sudden increase in the total number of Foraminifera accompanied by a definite 'wave' of calcareous forms. Thus, benthonic conditions were undisturbed and circulation of water unrestricted. It is noted that there was little glauconite in the samples.

**Assemblage 1** is within silts, siltstones, silty-sandstones, and sands. There is a sudden decrease in the total number of Foraminifera. This total number decreases further until Foraminifera are absent, higher in the section. Calcareous forms are rare and are mainly lagenids. Disturbed, turbid water conditions are lithologically evident and the progression from abundant faunas to no faunas suggests marginal marine conditions under probable brackish water (low salinity) conditions.

The distribution of some genera provides additional environmental information:

*Textularia* spp. are absent from the predominantly arenaceous Assemblages 1 and 5. They are present only in the black mudstone sediments. Burnaby (1962) and Jefferies (1962) show that *Textularia* spp. preferred relatively deep water during the deposition of the Upper Cretaceous in Western Europe. Stainforth (loc. cit.) states that *Textularia* is not affected by turbid water conditions.

*Gyroidinoides* spp. occur commonly in Assemblages 2 and 4 and are absent from Assemblages 1 and 5. Many authors, including Burnaby (loc. cit.) and Jefferies (loc. cit.), regard *G. nitida* as a deep water form, while Burnaby adds that no living species of *Gyroidina* or *Gyroidinoides* has been found at less than 60 fathoms.

Therefore, Assemblages 2, 3, and 4 are within a neritic sediment, deposited at a depth of 60 to 100 fathoms. These assemblages are within the Belfast Mudstone of the Port Campbell No. 2 section. The initial deposits, containing assemblage 5 (= the base of the Belfast Mudstone), and the final silt and sand deposits (= the Paaratte Formation), were deposited in shallow water (i.e. upper neritic to littoral).

The highest samples of dark mudstones in Port Campbell No. 1 and Flaxmans No. 1 contain a relative abundance of *Quinqueloculina* sp. with few *Gyroidinoides* spp. and *Textularia* spp. An abundance of *Quinqueloculina* spp. signifies shallow water deposits (Phleger 1960, p. 258). These facts suggest that the final dark mudstones were deposited in shallower water in Port Campbell No. 1 and Flaxmans No. 1 than in Port Campbell No. 2.

In Port Campbell No. 2, planktonic species were found only in Assemblage 2. Ammonite fragments were found associated with this foraminiferal assemblage. The absence of planktonic forms (including Mollusca) from Assemblage 1 & 5 is not surprising, as these faunas are within sediments which indicate a moderately high coastal runoff. Such conditions form a natural barrier to planktonic Foraminifera according to Phleger (1960, p. 259). The absence of planktonic forms from Assemblage 4 is puzzling, as this assemblage contains calcareous species in a slow forming sediment. In the case of Assemblage 3, it has already been stated that the depositional environment was anaerobic and would hinder the preservation of planktonic foraminiferal tests. But thick-shelled benthonic Mollusca (e.g. *Inoceramus*) are associated with Assemblage 3, so one could reasonably expect the preservation (original shell or at least moulds) of planktonic Mollusca. Enough samples have been examined to conclude that planktonic species (Foraminifera and Mollusca) did



not reach the depositional area during the accumulation of sediment which contains Assemblages 3 and 4 (in Port Campbell 2 and equivalent horizons in other bores). It follows that the depositional area must have been isolated from the open ocean during the accumulation of the dark mudstones which contain Assemblages 3 and 4.

An interesting feature of the planktonic Foraminifera is the absence of *Globotruncana* spp. and other planktonic genera of worldwide distribution in Turonian and Senonian sediments. There are few Turonian and Senonian deposits known at or south of the latitude of the Western Victorian deposits ( $38^{\circ} 30' \text{S.}$ ), but there is no reference to *Globotruncana* and associated genera in such deposits (refer to Wellman 1959, for New Zealand; and to Macfadyen 1933, for Terra del Fuego-Graham Land). It is also noted from Belford (1960) that *Globotruncana* is rare in the Gingsin Santonian (Western Australia, Lat.  $31^{\circ}\text{S.}$ ) but is much more common to the N. in the Santonian of the Lower Murchison R. (Lat.  $27^{\circ}\text{S.}$ ). Although evidence is not conclusive, it does suggest that *Globotruncana* had a latitudinal distribution in the Southern Hemisphere.

A definite latitudinal oceanic distribution of *Globotruncana* would imply a distribution influenced by latitudinal temperature variations, if the analogy with the present day was correct. Such latitudinal temperature variations are shown by oxygen isotope studies on the Senonian sediments of North America; Lowenstam & Epstein (1959, p. 71) illustrate a decrease in temperature towards the N. and give a palaeo-temperature of  $20^{\circ}\text{C.}$  for Lat.  $50^{\circ}\text{N.}$  These palaeo-temperatures are interesting as there are no reported occurrences of *Globotruncana* in the Turonian and Senonian of N. Alaska (Tappan 1960) and Turonian in N. Alberta (Stelck & Wall 1954). Cold water could account for the absence of *Globotruncana* in N. Alberta and N. Alaska. The Victorian Turonian and Senonian faunas have the same generic makeup as those of N. Alaska and N. Alberta. Therefore, the Victorian fauna could well have been a cold water fauna by reason of the above arguments, and because of the predominance of arenaceous forms.

#### (b) Facies

A facies sequence can be established for the series of vertical facies changes in the Port Campbell No. 2 Cretaceous section. The individual facies are numerous and have been grouped together into what is best described as 'vertical facies complexes', as each facies is the result of the same general environment as the complex to which it belongs. These 'vertical facies complexes' appear to be similar in concept to the 'facies tracts' which is a translation by Teichert (1958b, p. 2737) from a work in Russian by Nalivkin. But 'facies tract' implies more lateral facies changes within the same broad environment.

These 'vertical facies complexes' are identified by their broad lithological and palaeontological characters. The palaeontological characters have already been discussed. The 'vertical facies complexes' of the Port Campbell No. 2 sequence are discussed in ascending order. This facies sequence is fully detailed in Fig. 3.

- (i) Initial Detrital Deposits: Unsorted detrital material in a dark mudstone matrix. The amount and grain size decreases up the section, suggestive of the beginning of a sedimentary cycle. Arenaceous Foraminifera are present only. Palaeoecological studies suggest that the depositional environment was shallow, turbid, marine or semi-marine.
- (ii) Dark Mudstone Deposits: Black to dark grey mudstone-siltstone with amounts of glauconite and quartz. Lithologically, this 'complex' is homogeneous, but palaeoecologically it can be divided into 3 depositional environments:



- (a) The lower arenaceous-calcareous assemblage which signifies a neritic, clear water environment with good circulation on the sea floor but isolation from oceanic currents which would bear planktonic faunas.
  - (b) The arenaceous assemblage which signifies deep, clear water with apparently anaerobic benthonic conditions due to restrictions in water circulation.
  - (c) The upper arenaceous-calcareous assemblage which signifies deep, clear benthonic conditions with good water circulation both on the sea floor and on the surface which is open to oceanic currents, evident by the presence of a planktonic fauna.
- (iii) **Marginal Marine Deposits:** The term 'Marginal Marine Deposits' implies those deposits on the margins between land and sea, such as deltas, estuaries, lagoons and bays. The extent of marine influence can only be gauged by the presence or absence of marine faunas in the resultant sediment. In the Port Campbell No. 2 section there is a complex interval of sands and silts in varying grades and mixtures which could have been deposited in marginal marine environments. At the base of these deposits (at the top of the dark mudstones) there is a sudden decline in the total number of Foraminifera present (see Fig. 5) and palaeocological interpretation indicates shallow, turbid, brackish water. Higher in these deposits, the Foraminifera are less frequent and then completely disappear at what is probably the subtle (vertical) boundary between tolerable (brackish) and intolerable (fresh water) conditions. Essentially, this interval is within the same 'vertical facies complex' of Marginal Marine Deposits, but it is noted if Foraminifera are found, as they mark the vertical transition between marine and non-marine environments.

Ideally these 'vertical facies complexes' should have genetic designation referring to the broad depositional environment, thus retaining the analogy with Nalivkin's 'facies tracts'. The term 'Dark Mudstone Deposits' may appear incongruous, but the lithological homogeneity strongly implies genetic similarity; moreover, individual facies are indicated by palaeontological (and probably mineralogical) features which result from variations in the chemical environment on the depositional surface.

#### (c) The probable depositional environment

In Fig. 6, an attempt has been made to extrapolate the facies complexes between the known sections. This attempt is handicapped by the small number of control points and the distance between them. Yet a number of conclusions can be surmised, mainly along the Port Campbell to Warrnambool coastal strip. These conclusions are illustrated by the hypothetical three-dimensional diagram in Fig. 7.

The Initial Detrital Deposits are recognized in the two thickest sections, Port Campbell No. 2 and Flaxmans, although they are probably present in other sections. The unsorted detrital material is angular and often friable, with a matrix of clay and precipitated cement. These deposits may be diachronous as referred to elsewhere in this article.

The amount of coarse material decreases higher in the sequence and the finer grade Dark Mudstone Deposits predominate. The lowest Dark Mudstone Deposits contain neritic faunas, biostratigraphically assignable to Zonule B. These deposits are only present in Port Campbell No. 1 and No. 2 and in Flaxmans No. 1. Biostratigraphic equivalents of these deposits are found in no other facies. This suggests that the lowest Dark Mudstone Deposits (containing Assemblage 4 of the Port Campbell No. 2 section) formed in deep water at a time when Marginal-Marine

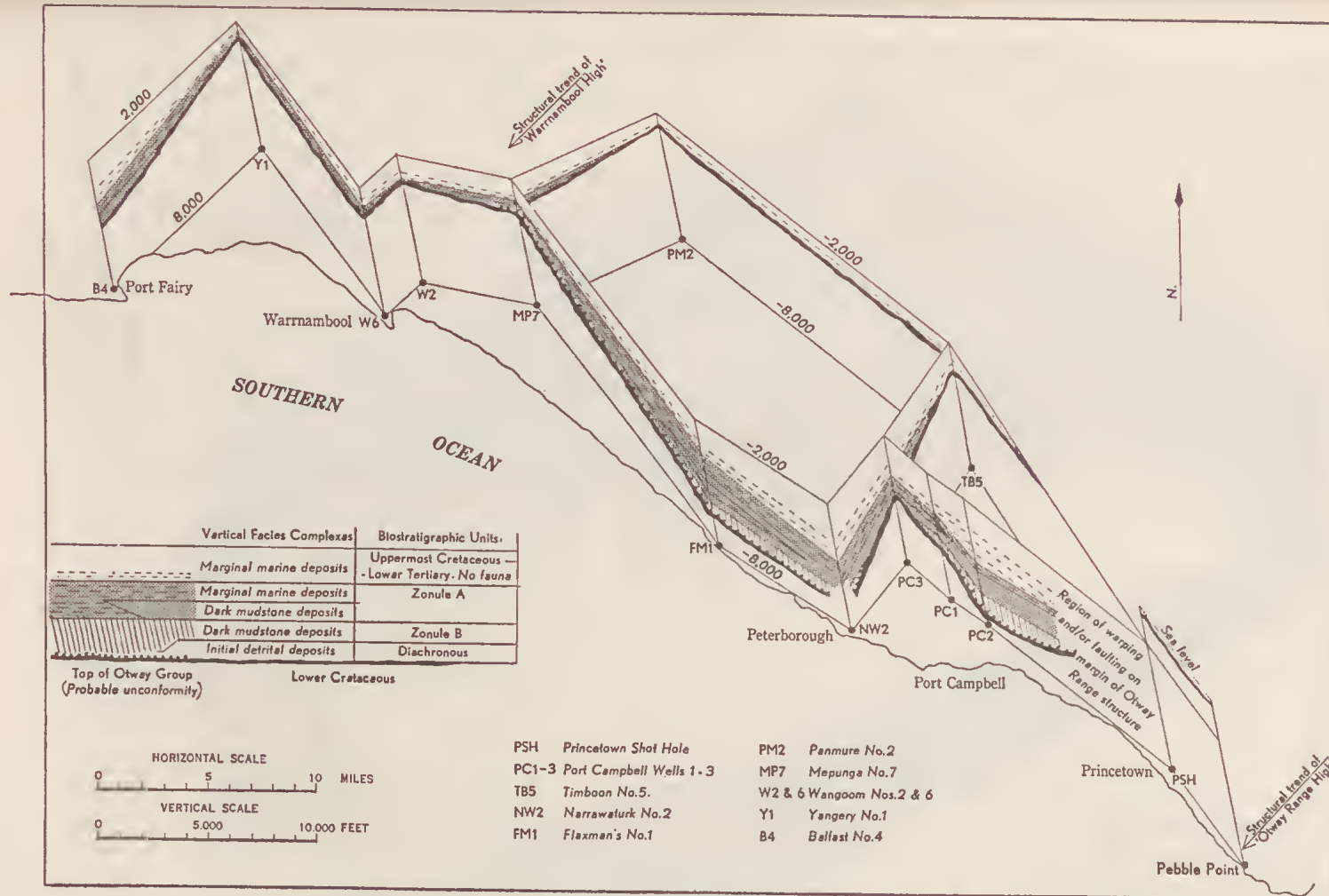


FIG. 6—Panel diagram showing Upper Cretaceous sediments in Port Campbell embayment.

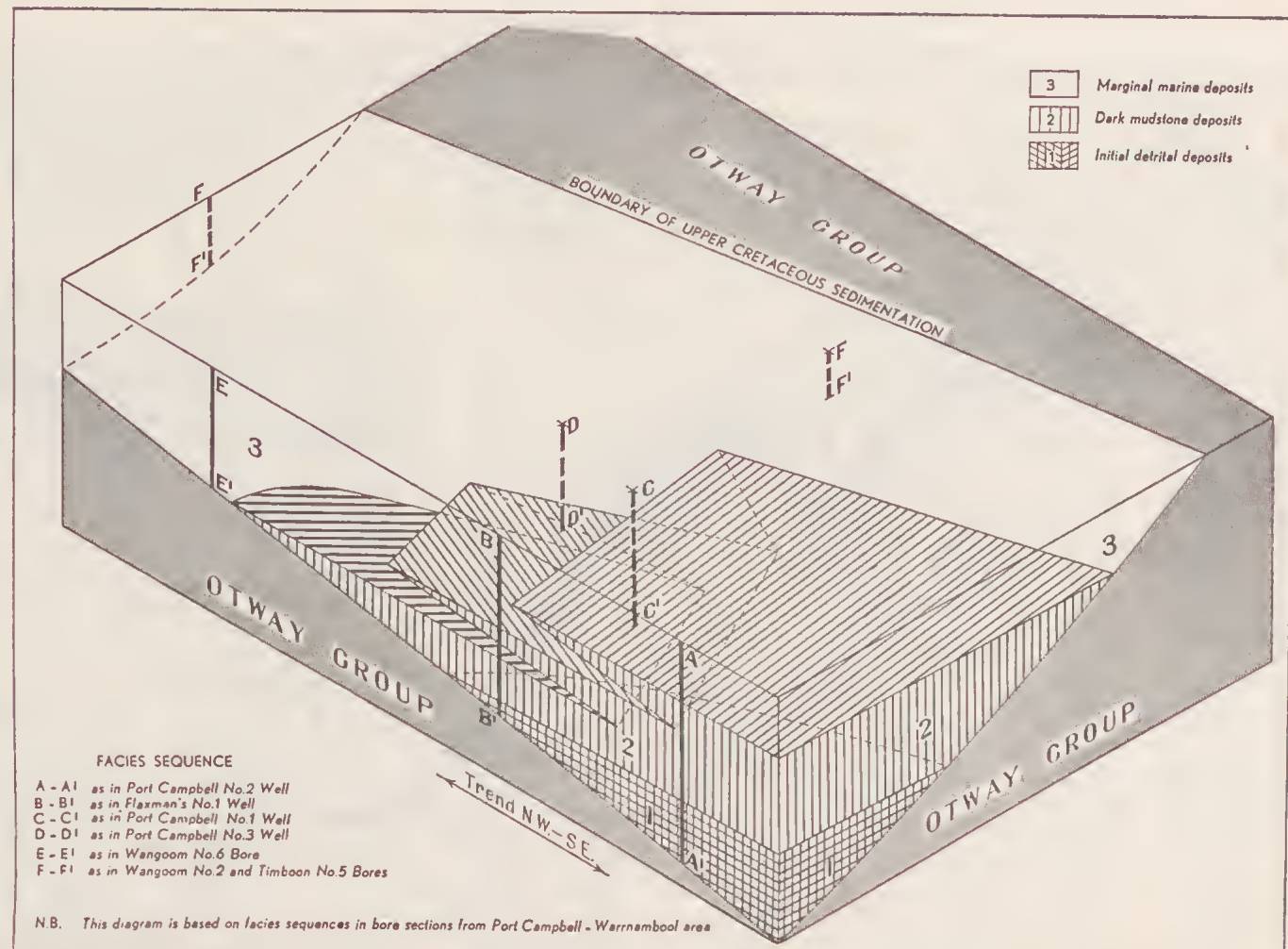


FIG. 7—Hypothetical block diagram of marine Cretaceous facies relationships in Victoria.



Deposits were not accumulating. This could imply slow contemporaneous down-faulting or downwarping from a low-lying land surface, the sediment being of an extremely fine nature.

Sediments containing the higher biostratigraphic unit, Zonule A, are found over a wider area, showing that sedimentation spread out to the N. and W. Zonule A faunas are found in both Dark Mudstones and Marginal-Marine Deposits. A sharp boundary, between the Dark Mudstone Deposits and overlying Marginal-Marine Deposits, is exhibited only in the Port Campbell No. 2 section. In all other sections, the transition between the two deposits is repetitious. This is clearly shown in the Flaxmans sequence where thin developments of Dark Mudstone Deposits re-occur within the Marginal-Marine Deposits over an interval of 1,000 ft. These repetitious Dark Mudstone Deposits contain faunas which indicate that they were formed in shallower water than the main mass of the Dark Mudstone Deposits. It is evident that shallow water conditions with facies interfingering existed to the N. and W., while the highest deep water Dark Mudstone Deposits were accumulating in the Port Campbell No. 2 section. This facies repetition and interfingering is illustrated in Fig. 7.

Thin Dark Mudstone Deposits are present in Port Campbell No. 3, while only marginal marine deposits are recognized in Timboon No. 5, Yangery No. 1, and the Wangoom bores.

The accumulated evidence shows the trend of sedimentation to have been from the SE. to the NW., though also trending slightly to the N. It would appear as if the depositional area was inundated with Marginal-Marine Deposits from the N. and W. At first, these deposits were deltaic or estuarine silts and sands, and were then covered by fresh-water lagoonal or marsh deposits (identified by absence of Foraminifera). Most of the Dark Mudstone Deposits were deep water sediments, but their relationship with the Marginal-Marine Deposits suggests that they were formed close to the shoreline. The Upper Cretaceous shoreline was at first retreating, but then gradually encroached over the depositional area, until its position was S. of the present shore line.

The sudden appearance of planktonic fauna is significant. These faunas occur in the top horizons of the Dark Mudstone Deposits. Their appearance indicates the breakdown of barriers which protected the depositional area from off-shore currents. Such barriers could include the actual direction of the currents (i.e. parallel to the shoreline), as well as off-shore rock or sand bars. Rock or sand bars could also inhibit the bottom water circulation which is believed to have influenced the fauna in portion of the Dark Mudstone Deposits. All evidence indicates that these mudstones were deposited, mainly, under 'barred basin conditions'.

To the W. of the Warrnambool area (Wangoom and Yangery bores) there appears to be a similar Upper Cretaceous marine transgression, evident in the Belfast No. 4 Bore, where there are 450 ft of Dark Mudstone Deposits with open marine conditions near the top. But the full extent and nature of Upper Cretaceous sedimentation is not known farther to the W. Only Marginal-Marine Deposits are recognized in the Pretty Hill section. Dark Mudstone Deposits are present, over a thin interval, in both Eumeralla No. 1 and Heywood No. 10. The dark mudstones in these wells are rich in glauconite and contain faunas suggestive of anaerobic conditions.

#### A REAPPRAISAL OF THE ROCK STRATIGRAPHY

From the preceding discussion, it can be concluded that all Upper Cretaceous sediments in SW. Victoria were deposited in a paralic environment. Under these

circumstances, a clear cut rock stratigraphy at a formation level may not be practical.

From the preliminary discussion on rock stratigraphy earlier in this article (Fig. 2), it could be concluded that there is a precise, natural delineation between the defined rock units; such a delineation is not verified by this study.

By definition, the term 'Belfast Mudstone' is restricted to a continuous sequence of dark grey mudstone/siltstone with varying amounts of quartz, mica, glauconite, and pyrite. Such a definition precludes any recognition of facies interaction, which is illustrated by the recurrence of Belfast Mudstone equivalents (Dark Mudstone Deposits) within the Paaratte Formation (e.g. Flaxmans No. 1 and Port Campbell No. 1). This is illustrated in Fig. 7; the two interdigitations of Dark Mudstone Deposits would be placed, by definition, within the Paaratte Formation as they are discontinuous in vertical sequence. Yet these interdigitations are laterally continuous and are clearly related to the main bulk of the Dark Mudstone Deposits which are designated as Belfast Mudstone. A reverse of this designation may be considered more logical. However, it is pointless to argue on this issue, as the Paaratte Formation and the Belfast Mudstone must be considered as having close affinities.

The boundary between the Belfast Mudstone and the underlying Flaxmans Beds is difficult to establish. The intervals assigned to the Flaxmans Beds do not contain Foraminifera. As a result of a detailed chemical and petrological investigation, Baker (1963) concludes that the Flaxmans Beds were deposited under marine conditions and mark the beginning of marine cycle of sedimentation. Baker's work suggests chemical conditions during the deposition of the Flaxmans Beds which would explain the absence of Foraminifera. The basal beds of the Belfast Mudstone (The Initial Detrital Deposits) are lithologically similar to the upper part of the Flaxmans Beds in Port Campbell No. 2 (as noted by Baker *loc. cit.*, p. 31). It is apparent that the Flaxmans Beds are the basal part of the marine Cretaceous sequence and are closely allied to the Belfast Mudstone.

The marine Cretaceous sequence is composed of 3 rock units, but the boundary between any two of these units is not clearly defined. Obviously the 3 units, Flaxmans Beds, Belfast Mudstone, and Paaratte Formation, should be placed within one rock unit of group status. Among other considerations, this would clearly separate these units from the non-marine Mesozoic Otway Group (including the Waarre Formation). No samples from the Otway or Merino Groups have been found to contain spores or pollen younger than Lower Cretaceous (see Cookson & Dettmann 1958). The base of the Belfast Mudstone is regarded as Turonian and the upper part of the Belfast Mudstone, as well as the Paaratte Formation, is within the Senonian. The age of the Flaxmans Beds is not yet clearly stated, but is probably Upper Cretaceous (Cenomanian or Turonian). These Cretaceous units are therefore stratigraphically above the Otway Group and could not be laterally interconnected with the Otway Group.

However, the group of marine Cretaceous units is not clearly separated from the overlying Wangerrip Group. The Paaratte Formation is basically a paralic unit of sands and silts in various grades and mixtures; sediments of a calcareous nature are rare. The Wangerrip Group fits the same broad description. Both units contain glauconite and marine fossils at various horizons. There is no evidence of a disconformity between them. In fact, the designated base of the Wangerrip Group in Flaxmans No. 1 Well contains Cretaceous Foraminifera; usually the designated base is devoid of Foraminifera.

It should be remembered that the Wangerrip Group was defined by Baker (see



Baker 1953) from outcrop section with the Palaeocene Pebble Point Formation as the basal unit. Moreover, Baker (1943, p. 244) comments on the overlap of the Pebble Point Formation on Otway Group and states—'On account of this overlap, it is reasonable to assume that still older members of the Eocene series may be hidden below sea level west and north-west of the Pebble Point Beds. Boring operations will be required to establish this point.' Baker's assumption has been established in that sediment exists conformably below the Pebble Point Formation and unconformably overlying the Otway Group. But instead of being older members of the Eocene series, they are of Upper Cretaceous age and, once again, it should be noted that the Pebble Point Formation is now considered to be of Paleocene age.

It is shown in this paper that Upper Cretaceous sedimentation took place on a sloping surface and that there was a gradual transgression up this slope. Baker (*loc. cit.*) has already commented on the transgressive nature of the Pebble Point Formation over a short distance. It is probable that the Pebble Point Formation represents the ultimate extension of this 'up slope' transgression, while the Flaxmans Beds (in Port Campbell No. 2) represent the beginning of this cycle of transgressive sedimentation. There are close lithogenetic similarities between these two units but, at the present time, it is not certain if they represent the same diachronous facies. This implies that the Wangerrip Group (of Baker 1953) could be extended down to include lithogenetically similar rock units of Upper Cretaceous age. A thorough study of the basal Tertiary sediments is now being undertaken and no firm decision on this matter will be made until the final results are compiled.

However, the present situation is unsatisfactory because of difficulties in recognizing the Pebble Point Formation away from the marginal area as is to be expected from the preceding discussion. Palaeontology does not assist in identifying the equivalents of the Pebble Point Formation, for, although Paleocene foraminiferal faunas are common in sub-surface sections, these faunas are younger than the 'Pebble Point Fauna'.

An alternative suggestion is that the Wangerrip Group be made a sub-group of a new unit which embraces all these paralic, lower Tertiary and Upper Cretaceous sediments.

## STRUCTURAL RELATIONSHIPS

There is a direct relationship between the areal distribution, nature and thickness of the Upper Cretaceous sediments and the present sub-surface contours of the top of the Otway Group. The Upper Cretaceous is thickest where the top of the Otway Group is deepest (e.g. Port Campbell No. 2), where the top of the Otway Group is shallower the Upper Cretaceous is poorly developed, and is absent where the top is above 2,000 ft. Biostratigraphic studies (illustrated in Fig. 6) show that the oldest Upper Cretaceous faunas (Zonule B) are present only where the top of the Otway Group is below 5,300 ft. Similarly, facies studies (in Fig. 6) demonstrate that the thickest section of pure marine sediments (Dark Mudstone Deposits) is where the contact is deepest and a higher proportion of Marginal-Marine Deposits are developed as the top of the Otway Group becomes shallower.

These facts suggest that the Upper Cretaceous seas transgressed up a sloping surface. They also suggest that Upper Cretaceous sedimentation was controlled by the surface configuration of the Otway Group at the time of deposition. It follows that the Upper Cretaceous sediments unconformably overlies the Otway Group.

Outcrop and sub-surface information reveal that the Otway Group has a definite



structural configuration. The general structural trend is SW.-NE. This trend is apparent from the exposures in the Otway Ra. (Thomas 1959). A similar trend is noted running NE. from Warrnambool. Some 30 miles NE. of Warrnambool, bores at Glenormiston and L. Bookar pass directly from the Tertiary into Palaeozoic. S. and SW. of these bores, the Otway Group is present below the Tertiary cover and the top of the Otway Group deepens towards Warrnambool, as well as towards Port Campbell. Thus, a line drawn from Glenormiston to Warrnambool appears to be the axis of a SW.-plunging anticline. (The Tectonic Map of Australia shows this structure as a SW.-plunging syncline, due to insufficient sub-surface data at the time of compilation—1958.)

The Upper Cretaceous seas transgressed over the low-lying area between the Otway Ra. structure and the Warrnambool structure, as well as on to the plunging nose of the Warrnambool structure. But the configuration of the top of the Otway Group is not symmetrical about a medial axis between the two anticlinal structures. The greatest vertical displacement of the Otway Group is relatively close to the Otway Ra. structure. The magnitude of this displacement decreases NE. from the coast, until the Warrnambool structure appears to coalesce with the Otway Ra. structure. Maximum development of marine Cretaceous sediments is close to the Otway Ra. structure and the sedimentary trend (of the marine Cretaceous) is from the SE. to the NW., perpendicular to the structural trend. Thus the Upper Cretaceous depositional area is not in a simple syncline.

The explanation of the above is, that the Otway Ra. structure must have been a stable structure, so that movement on the more mobile Warrnambool structure would have caused deformation between the two structures. This deformation would have been in the form of warping and faulting and would be more pronounced closest to the stable structure (i.e. the Otway Ra. structure). Such a mechanism apparently initiated Upper Cretaceous sedimentation and persisted contemporaneously with the deposition, thus explaining the vast differences in the base levels of many horizons of Upper Cretaceous and lower Tertiary sediments.

This area of Upper Cretaceous sedimentation is commonly referred to as the 'Port Campbell Embayment'. (This term has not appeared previously in print, but the author is not its sole user.) W. of the Warrnambool structure, the Upper Cretaceous depositional area could be referred to as the 'Portland Embayment'. The marine Dark Mudstone Deposits at Port Fairy (Belfast No. 4 Bore) are separated from those in the 'Port Campbell Embayment' by the Marginal-Marine Deposits on the Warrnambool structure. During the lower Tertiary, sedimentation was continuous and uninterrupted over the Warrnambool structure, thus the 'Port Campbell Embayment' and the 'Portland Embayment' became one depositional area. This is referred to as the Portland Sunkland (of Boutakoff 1952) or sometimes as the Western District Basin.

Little is known of the structural situation in the 'Portland Embayment', save for the obvious deepening towards Port Fairy (see above). Drilling at Pretty Hill revealed a structural high, as the top of the Otway Group (? Merino Group) was at 2,719 ft. and the bore intersected Cambrian diabase at 7,671 ft. Farther W., in Eumeralla No. 1, the top of the Otway Group was at much the same level (2,940 ft), but the Cambrian was not encountered in 10,000 ft of drilling. In Heywood No. 10, drilling ceased while still in Upper Cretaceous at 5,290 ft. No Mesozoic sediments were encountered in 5,500 ft of drilling at Portland. The exposure of non-marine Mesozoic rocks (Merino Group) and lower Tertiary rocks in the Casterton area indicates that this is a structural high. This feature is referred to by

Boutakoff (1952) as the Dartmoor Ridge. It can only be surmised that similar structural mechanisms existed in the 'Portland Embayment' as probably existed in the 'Port Campbell Embayment'.

The absence of Upper Cretaceous sediments from the Otway Ra. is not surprising if this area was structurally stable and the transgressive sedimentation gradually encroached on to it. Edwards (1962, p. 108) discusses basal marine Tertiary remnants in contact with the Otway Group, well above sea-level, at Cape Paton and Benwerrin. This shows that the Tertiary part of the Wangerrip Group overlapped farther E. than Pebble Point. The extent of the basal Tertiary depositional area is certainly greater than that of the Upper Cretaceous. The suggestion is that an equilibrium of level may have been reached, due to Cretaceous filling of the weaker down-warped (or faulted) area and the erosion of the stable areas.

Edwards (loc. cit., p. 116-118) provides evidence that the Otway Ra. were domed up as a result of fault and fold movements in late Cainozoic times. Structural evidence from the Upper Cretaceous sediments shows that the late Cainozoic structural movements were not the only ones that have affected the Otway Ra. and the region to the W.

### Addendum

Since the completion of the preceding text, another marine Cretaceous section has been drilled by the Victorian Mines Department. This section is between 2,954 ft and 3,498 ft in Mepunga No. 7 Bore at Allansford (8 miles E. of Warrnambool). The sediments between 2,954 ft and 3,390 ft are Marginal-Marine Deposits containing mainly arcaceous Foraminifera of Zonule A. These results fit into the framework of marine Cretaceous sedimentation already established in this text.

The interesting feature of the Mepunga section is the presence of Initial Detrital Deposits between 3,390 ft and 3,498 ft. These sediments probably represent the Flaxmans Beds. Sections of a core of sideritic sandstone (3,413 ft to 3,428 ft) revealed arenaceous Foraminifera including *Haplophragmoides* sp. A. Therefore, these Initial Detrital Deposits contain Zonule A and, therefore, are younger than those of the Port Campbell No. 2 and Flaxmans section which contained Zonule B faunas.

This information supports the author's views, expressed earlier in this article, that the Initial Detrital Deposits were transgressive and probably diachronous. It is now obvious that the Detrital Deposits and the Flaxmans Beds are represented by the same interval of sediment.

It is also noted that the Flaxmans Beds are reported in Pretty Hill No. 1 (see Table 1) to the W. of Warrnambool. The interval assigned to these beds was not cored and, as contamination was heavy, it is not possible to comment on the biostratigraphic position of this interval.

Fig. 6 has been redrafted to accommodate the Mepunga information and to include the entire interval of the Flaxmans Beds, where recognized, within the Initial Detrital Deposits. No other figure has been amended for this information, as it was felt unnecessary at this stage.

### Part B: The Foraminifera

Only 75% of the foraminiferal fauna has been monographed, due to poor preservation of many specimens or not enough available specimens to trace variability within species. Generic reappraisal of many species proved impossible because of poor preservation, lack of specimens, and difficulties of cutting sections.

The species index, which appears later, lists all species recorded in the samples examined. This index includes the indeterminant species as well as the described ones. Apart from Port Campbell No. 2, the faunal distribution charts of all sections examined are not included in this paper, but are available for inspection from the library of the Victorian Geological Survey.

Where a new species is described, a holotype is designated. If variation is recognized within the new species, the range of variation is described and illustrated by selecting 'supplementary specimens', thus dispensing with the typological concept of the paratype. This is in accordance with the views of Simpson (1961), who states that 'populations, not individuals, are the units of systematics and are the things classified'. It should be noted that the selected 'supplementary specimens' may not come from the same sample as the holotype, and some 'supplementary specimens' are selected to illustrate differences in preservation rather than intra-specific variation.

The specimens of described species are illustrated in Pl. LXXIX-LXXXVI. The figures of Pl. LXXIX-LXXXIV are camera lucida drawings by Mrs I. G. Knight. The figures of Pl. LXXXV-LXXXVI are photomicrographs of thin sections. The sections were photographed through a polarizing microscope. Some of the photomicrographs were taken with crossed nicols.

All specimens illustrated are registered and housed in the Geological Survey Museum of the Department of Mines, Melbourne. The registered numbers (e.g. GSM 58699) and the sources of the specimens are given in the appropriate specific description.

Dr M. F. Glaessner allowed the author to examine his collection of Victorian Cretaceous Foraminifera (made on behalf of Frome-Broken Hill Co. Pty Ltd). Any use of this collection is noted in the text.

### Genus *Hyperammina* Brady 1878

#### *Hyperammina elongata* Brady

(Pl. LXXIX, fig. 1, 2)

- 1878 *Hyperammina elongata* Brady, *Ann. & Mag. Nat. Hist.* ser. 5, 1: 433, Pl. 20, fig. 2.  
 1946 *Hyperammina elongata* Brady, Cushman, *Prof. Pap. U.S. Geol. Surv.* 206: 15, Pl. 1, fig. 12, 13 (with synonymy).  
 1958 *Hyperammina elongata* Brady, Pokorný, *Mikropalaontologie*, Berlin, 1: 168, Fig. 57.

The test consists of a long simple cylindrical tube leading from an inflated proloculus, which has partially collapsed in all specimens. The test wall consists of cemented fine quartz grains which are usually clear and white in contrast with the darker material of the arenaceous tests of other species in the sequence. Maximum diameter of proloculus approximates 0.3 mm in all specimens. Maximum length of tube = 0.7 mm.

**DISCUSSION:** It is unusual to isolate complete specimens as the tube becomes detached easily from the proloculus. A solitary tube can be mistaken as a straight slender *Bathysiphon*, while a detached proloculus resembles *Saccamina* or *Pelossina*. A detached proloculus as well as a complete specimen are illustrated.

**DISTRIBUTION:** The random distribution of this species lacks stratigraphic significance.

**FIGURED SPECIMENS:** Pl. LXXIX, fig. 1—GSM 58716 from a core sample at 4,126 ft in Flaxman's No. 1; fig. 2—GSM 58717 from a core sample at 5,231 ft in Port Campbell No. 1.



Genus *Haplophragmoides* Cushman 1910

*Haplophragmoides* is the most abundant genus of Foraminifera in the Victorian Cretaceous. Specific determination has proved difficult. Numerous Cretaceous species are described in the literature, but the differences between many of them are slight and specific variation is sometimes inferred but seldom discussed. Compression or distortion of the test is prevalent, which adds to the difficulties in specific comparison.

The following features have been used as specific characters in described species:

- (1) Size and shape of test: round to flattened (distortion is usually considered).
- (2) Form of coiling: involute, partially evolute, wholly evolute. In a loosely coiled species this feature can vary.
- (3) Number of chambers: often taken as a characteristic constant. Sometimes it is the only feature that distinguishes between species.
- (4) Periphery: rounded or acute; in outline rounded to lobulate.
- (5) Nature and depth of umbilicus.
- (6) Sutures: straight or curved; width and degree of distinctness; raised, flushed, or depressed.
- (7) Composition of test. Regarded as an important character by some authors. Tappan (1957, p. 203) shows that the test composition of *H. toporukensis* varies according to the associated lithology. Similar observations have been made on *Haplophragmoides* in the Victorian sequence. Therefore, this feature is not considered as a specific character in this discussion.

3 definite species have been established in the Victorian sequences. Each species differs from the others in at least 2 of the first 6 features listed above. But each of these 3 species differs from certain described species in only one feature. Classification on a specific level would be simple if each Victorian species had close affinities with only one described species. Formal designation has not been attempted, as the Victorian species have purely local significance. Specific identification, within the sequence, has been achieved by referring to them as *Haplophragmoides* species *A*, *B*, and *C*.

*Haplophragmoides* sp. *A*

(Pl. LXXIX, fig. 3)

The bi-umbilicate test is somewhat flattened with an acute periphery, lobulate in outline. There are 8-10 triangular shaped chambers in the outer whorl. This whorl is superimposed on the two earlier whorls, though not completely overlapping them, as the test is partially and irregularly evolute. The sutures are thickened, straight to noticeably curved back and are slightly depressed. The umbilicus is deep with a flattened umbilical margin. The aperture is a sutural slit at the base of the last chamber.

The test is composed of siliceous cement with varying amounts of arenaceous material. Where the siltstone is sandy, higher in the sequence (the Paaratte Formation), the tests have roughened exteriors with a large amount of coarse arenaceous material. In the fine grained Belfast Mudstone the tests are composed of mainly siliceous cement with a small proportion of fine grained arenaceous material. Compression is a common feature, but many specimens from the Belfast Mudstone are infilled with pyritic mud and appear to have resisted deformation.

The maximum diameter of specimens ranges from 0.5 mm to 1.2 mm. The undeformed figured specimen has a thickness of 0.25 mm for a maximum diameter of 0.64 mm.

**AFFINITIES:** This species has close affinities with the following species, but differs in that:

*H. gigas* Cushman, has sigmoidally curved, narrow sutures.

*H. rota* Nauss, has indistinct sutures and the peripheral outline is rounded.

*H. rudis* Bolin, has narrow sutures.

*H. excavatus* Cushman & Waters, has raised sutures. (Collapsing of the chambers in some specimens of *H. sp. A.* produces close similarities.)

**DISTRIBUTION:** Common to abundant in Zonule A, though rare at the top of the Zonule. Has not been identified positively in core samples from Zonule B.

**FIGURED SPECIMEN:** Pl. LXXIX, fig. 3—GSM 58713 from a core sample at 5,231 ft in Port Campbell No. 1.

### **Haplophragmoides sp. B**

(Pl. LXXIX, fig. 4)

The bi-umbilicate test has a rounded periphery. It is loosely coiled, the 2 inner whorls being evolute to varying degrees, but never completely evolute. There are 8 chambers in the outer whorl. The straight radial sutures are thickened and the last 2 sutures may be slightly depressed. The umbilicus is broad, deep, and with a rounded umbilical margin. The aperture is a sutural slit at the base of the last chamber.

The amount and coarseness of arenaceous material in the test varies, reflecting the type of sediment as described for *H. sp. A.* Test deformation is common.

The maximum diameter varies from 0.4 mm to 0.7 mm and the thickness from 0.15 mm to 0.32 mm.

**AFFINITIES:** This species has close affinities with the following species, but differs in that—

*H. atahallpai* Frizzell, has 11 chambers with deeply impressed sutures.

*H. carlilensis* Fox, has 10 chambers.

*H. collyra* Nauss, has a lobulate periphery.

*H. flagleri* Cushman & Hedberg, has 8-10 chambers and the sutures are narrow.

*H. toporukensis* Tappan, is a species embracing a range of variation which could include *H. sp. B.*, but the latter species does not exhibit such wide variation.

**DISTRIBUTION:** Present throughout the Victorian sequence.

**FIGURED SPECIMEN:** Pl. LXXIX, fig. 4—GSM 58715 from a sample from 5,200 ft to 5,210 ft in Flaxman's No. 1.

### **Haplophragmoides sp. C**

(Pl. LXXIX, fig. 5)

The somewhat flattened, bi-convex test has a rounded to sub-rounded periphery and a rounded peripheral outline. The test is completely involute. The whorl consists of 6 chambers. The distinct straight, radial sutures coalesce at the centre of each face. There is no umbilical hollow. The aperture is a sutural slit at the base of the last chamber. The tests are composed of fine grained arenaceous material with a siliceous cement. There is no variation in test composition. Many specimens have an acute periphery but this is due to deformation, as the specimens are not symmetrical in side view.

In undeformed specimens the maximum diameter ranges from 0.5 mm to 0.65 mm, while thickness ranges from 0.2 mm to 0.3 mm.

**AFFINITIES:** This species shows close affinities with the following species, but differs in that—

*H. kirki* Wickenden, has depressed sutures and thus a lobulate periphery.

*H. dickinsoni* Crespin, from the Lower Cretaceous of the Australian Great Artesian Basin, with rounded periphery, slightly lobulate in outline.

*H. obesus* Takayanagi, has a globular test with a well rounded periphery.

**DISTRIBUTION:** Associated with *H. sp. A* though less frequent.

**FIGURED SPECIMEN:** Pl. LXXIX, fig. 5—GSM 58714 from core sample at 5,910 ft in Port Campbell No. 2.

Genus *Ammobaculites* Cushman 1910

*Ammobaculites* cf. *fragmentaria* Cushman

(Pl. LXXIX, fig. 10, 11)

1927 *Ammobaculites fragmentaria* Cushman, *Trans. Roy. Soc. Canada* 3rd ser., 21 (4): 130, Pl. 1, fig. 8.

Long rectilinear, tapering test consists of a small, compressed, planispiral initial portion followed by 6-8 uncoiled chambers. The greatest width is in the final chamber, and the uncoiled chambers are ovoid in cross section. The sutures are straight, depressed and distinct in the uncoiled portion, but are obscured in the coiled portion. The walls are composed of cemented coarse grained quartz. In some specimens the quartz grains are extremely large (up to 0.2 mm in length) and ferromagnesian minerals are incorporated also in the walls. The aperture is elliptical and terminal.

The length of specimens ranges from 0.9 mm to 1.2 mm; maximum width of 0.2 mm to 0.3 mm.

**DISCUSSION:** The Victorian specimens are typical of the Holotype of *A. fragmentaria* Cushman from the Senonian of Canada, but not of specimens illustrated by Cushman (1946, Pl. 3, fig. 10-16) from the Albian of the Gulf Coast region of America as *A. fragmentarius*. But the Victorian specimens have a roughened exterior and not a surface composed of flat flakes of quartz as in the Canadian material. The external appearance of the test walls appears to have been taken as a specific characteristic so that the Victorian material does not agree entirely with the specific definition. However, composition of arenaceous tests may well be more an environmental than specific feature.

*A. cf. fragmentaria* is distinct from *A. subcretacea* because of the tapering test, relatively small initial coil and more chambers in the uncoiled portion.

**DISTRIBUTION:** Recognized only in Zonule A of the sequence where the species is associated with the *A. subcretacea* and *A. goodlandensis*.

**FIGURED SPECIMENS:** Pl. LXXIX, fig. 11—GSM 58673 from a core sample at 4,983 ft in Flaxmans No. 1; fig. 10—GSM 58674 from a core sample at 4,983 ft in Flaxmans No. 1.

*Ammobaculites goodlandensis* Cushman & Alexander

(Pl. LXXIX, fig. 6)

1930 *Ammobaculites goodlandensis* Cushman & Alexander, *Contr. Cushman Lab.* 6 (1): 8, Pl. 2, fig. 7-8.

1954 *Ammobaculites goodlandensis* Cushman & Alexander, Frizzell, *Rep. Inv. Univ. Texas Bur. econ. Geol.* 22: 62, Pl. 2, fig. 20.

The robust test consists of a broad initial coil and 2-3 uncoiled chambers. The



initial portion is depressed centrally while peripherally the chambers are raised. Sutures are indistinct but are depressed. The uncoiled chambers are irregularly shaped and ovoid in transverse section. The simple aperture is terminal. The arenaceous test walls consist of cemented coarse grains of quartz (up to 0.15 mm long), with small quantities of mica, ferromagnesian minerals, and fragments of calcareous foraminiferal tests. The coarse grained wall composition obscures much detail.

Length of specimens ranges from 0.7 mm to 1 mm; maximum diameter (diameter of coil) from 0.6 mm to 0.38 mm. The maximum thickness is in the uncoiled chambers and is 0.25 mm for all specimens.

**DISCUSSION:** Victorian specimens are typical of this species which is recorded from sediments of Albian age in the Gulf Coast of America. Some specimens without uncoiled chambers have been assigned to this species.

**DISTRIBUTION:** Distribution is widespread throughout the Victorian sequence.

**FIGURED SPECIMEN:** Pl. LXXIX, fig. 6—GSM 58675 from a core sample at 7,403 ft in Port Campbell No. 2.

### ***Ammobaculites subcretacea* Cushman & Alexander 1930**

(Pl. LXXIX, fig. 7-9)

- 1930 *Ammobaculites subcretacea* Cushman & Alexander, *Contr. Cushman Lab.* 6 (1): 6, Pl. 2, fig. 9, 10.  
 1946 *Ammobaculites subcretacea* Cushman & Alexander, Cushman, *Prof. Pap. U.S. Geol. Surv.* 206: 23, Fig. 18-20.  
 1952 *Ammobaculites subcretacea* Cushman & Alexander, Brotzen, *Senck.* 33 (4/6): 319, Pl. 1, fig. 8; Pl. 2, fig. 1-9.

The coarse arenaceous test is elongate and compressed laterally. The initial portion consists of 5-7 chambers which are planispirally coiled. The coiled portion is followed by a linear series of 3-4 chambers. The linear chambers are widest immediately after the sutures. The coiled portion is wider than any of the linear chambers. Generally, the linear chambers are flattened in the same plane as the coiling, but in a few specimens the flattening is in the plane perpendicular to that of the coiling. The simple ovoid aperture is terminal, on the tapering neck of the final chamber.

The length in 50 specimens ranges from 0.7 mm to 1 mm.

**ADDITIONAL NOTES ON TEST COMPOSITION:** The test walls are mainly composed of cemented quartz, with considerable variation in grain size. In some specimens a small amount of mica flakes and a black ferro-magnesian mineral have been incorporated with the test. As can be seen in Pl. LXXIX, fig. 8, the coarser grains in the outer wall of the linear chambers are orientated in the direction of growth, so as to produce a series of ridges and furrows. Although this is not a unique feature in the specimens studied, it is not of specific significance. Other specimens have the same chamber arrangement and shape but the quartz grains are arranged at random, as they are on the type figures of *A. subcretacea*.

**OCCURRENCE:** This species occurs throughout Zonule A. Only in a core sample from 5,231 ft in Port Campbell No. 1 Well is it an important constituent of the assemblage. Occurs in the Lower Cretaceous in North America, but probably ranges up to the Turonian in Europe (Brotzen).

**FIGURED SPECIMENS:** Pl. LXXIX, fig. 7—GSM 58677 from a core sample at 5,231 ft in Port Campbell No. 1; fig. 8—GSM 58678 from a core sample at 5,231 ft

in Port Campbell No. 1; fig. 9—GSM 58676 from a core sample at 5,231 ft in Port Campbell No. 1.

### Genus *Textularia* DeFrance 1824

Difficulty has been encountered in generically classifying the Victorian Cretaceous textularid forms. Intrinsically, they are all within the genus *Textularia*, but the significance of the initial planispiral coil of some specimens cannot be ignored. It has been shown by Glaessner (1945, p. 98) and others, that the genotype of *Bolivinopsis* Yakovlev 1871 has arenaceous walls. This genus is separated from *Textularia* because the initial coil is equal to or of greater width than the width of the biserial part of the test, at least in the microspheric forms. None of the species described below exhibits this character. However, it is not generally accepted that *Spiroplectammina* Cushman 1927 is a synonym of *Bolivinopsis*. Although *Spiroplectammina* lacks apparent validity, it cannot be ignored because of its use in recent literature. Its generic character is that the initial coil forms a considerable portion of the test in both the microspheric and megalospheric forms. Only one of the species described below, *T. semicomplanata* Carsey, has definitely an initial coil in all specimens, but this coil is but a small portion of the test. Even if *Spiroplectammina* is a valid genus, the Victorian textularids should still be placed within the Genus *Textularia*.

### *Textularia anceps* Reuss 1860

(Pl. LXXIX, fig. 12-15; Pl. LXXXV, fig. 2, 3 (sections))

1860 *Textularia anceps* Reuss, *Sitzber. Akad. Wiss. Wien* 44: 234, Pl. 13, fig. 2.

1957 *Spiroplectammina anceps* (Reuss), Hofker, *Beih. Geol. Jb.* 27: 60, Fig. 56 a-d.

The long wedge-shaped finely arenaceous test is medially thickest. Transversely, the shape is rhomboidal though rounded. The sutures are distinct, depressed, and angled backwards slightly in the biserial part of the test. The narrow slit aperture is at the base of the notch in the final chamber face.

There is considerable diversity within the Victorian specimens of this species. Both microspheric and megalospheric forms are recognized. The larger megalospheric forms have 8-10 pairs of biserial chambers and no indication of initial coiling, while the initially coiled microspheric forms are smaller and have 4-6 pairs of biserial chambers. Some specimens of both forms exhibit inflation of the last pair of chambers and are longitudinally curved. A selection of forms has been illustrated and the dimensions and features are summarized in Table 2.

**DISTRIBUTION:** In the Victorian Cretaceous sequence this species is found in Zonule A where it is common, although it is not found in the upper part of the Zonule. It is often associated with *Textularia semicomplanata* Carsey. *T. anceps* occurs in the Senonian of Europe.

### *Textularia semicomplanata* Carsey 1926

(Pl. LXXX, fig. 1, 2; Pl. LXXXV, fig. 1 (section))

1926 *Textularia semicomplanata* Carsey, *Texas Univ. Bull.* 2612: 25, Pl. 3, fig. 4.

1931 *Spiroplectammina semicomplanata* (Carsey) Plummer, *Texas Univ. Bull.* 3101: 129, Pl. 8, fig. 7.

1946 *Spiroplectammina semicomplanata* (Carsey) Cushman, *Prof. Pap. U.S. Geol. Surv.* 206: 28, Pl. 6, fig. 5-14 (with detailed synonymy).

The fine grained arenaceous tapering test has a maximum width which is always greater than half the length. The test is thicker medially and this thickness increases with chamber addition, while the margin is sharp. The apertural end is rhomboidal.

TABLE 2

Reg. No. GSM	Pl., fig.	Length (mm)	Max. thickness (mm)	Max. width (mm)	Comments	Locality
Microspheric Forms:						
58741	LXXIX, 12	0.52	0.25	0.27	Final chambers inflated. Longitudinal section.	Port Campbell No. 1 core at 5025 ft.
58742	LXXIX, 15	0.51	0.22	0.32		„
58802	LXXXV, 2	0.52		0.26		„
Megalospheric Forms:						
58743	LXXIX, 13	0.8	0.23	0.33	Final chambers greatly inflated. Section last chamber inflated.	„
58744	LXXIX, 14	0.72	0.39	0.45		Port Campbell No. 1 core at 4710 ft.
58801	LXXXV, 3	0.6		0.27		„

Initially 3 or 4 chambers form half a coil round the proloculus. This is followed by 4 to 6 pairs of biserially arranged chambers. The chambers are not inflated although their dimensions increase progressively. The sutures are distinct though slightly depressed, and the biserial chamber sutures curve gently backwards towards the periphery. The terminal face is gently curved. The aperture is a narrow slit-like opening at the base of the apertural face.

The maximum length of the specimens vary from 0.35 mm to 0.45 mm, width from 0.27 to 0.33 mm, thickness from 0.14 mm to 0.16 mm. The width of the coiled portion never exceeds 0.15 mm.

**DISCUSSION:** The Victorian specimens exhibit little variation. They fit within the range of specific variation illustrated by Cushman (1946), although the Victorian specimens appear to be a little thicker compared to their length.

**DISTRIBUTION:** Associated with *T. anceps*. Not identified in Zonule B, nor are they present in the upper part of Zonule A. Occurs in the Senonian and Maastriichtian of North America.

**FIGURED SPECIMENS:** Pl. LXXX, fig. 1—GSM 58745 from a core at 5,025 ft in Port Campbell No. 1; fig. 2—GSM 58746 from a core at 5,025 ft in Port Campbell No. 1; Pl. LXXXV, fig. 1—GSM 58803 from a core at 5,025 ft in Port Campbell No. 1.

### ***Textularia trilobita* sp. nov.**

(Pl. LXXIX, fig. 16, 17; Pl. LXXXV, fig. 4, 5)

**DIAGNOSIS:** The robust, fine grained, arenaceous test is of a shiny appearance. The maximum width is greater than half the length. The test is convex on both sides, rising from sharp periphery to a rounded axial ridge. Initially, the margin is rounded, but becomes roughly parallel with serrations where the sutures meet the



margins. Transversely, the test is rhomboidal. In the biserial portions of the specimens, the sutures are narrow, depressed, and curve back at  $30^\circ$  to the axis. The terminal chamber overlaps the preceding chambers on one side of the test but not on the other. The abrupt final face has a semi-circular notch with a narrow aperture at the base of the notch.

All specimens exhibit the characters outlined above, but the specimens can be divided into 3 forms.

- (a) Microspheric form: has an initial end consisting of half a whorl of 4 chambers with a globular proloculus. The chambers curve in the direction of growth. The initial chambers are followed by 3 to 6 pairs of biserially arranged chambers.
- (b) Megalospheric form: is difficult to distinguish on external features. A longitudinal section reveals that there is no initial coil. There are as many as 12 pairs of biserially arranged chambers.
- (c) Juvenile form: has only one pair of biserial chambers. The width of the specimens is greater than the length. Only the microspheric form is known for this growth stage.

The length of specimens ranges from 0.25 mm (juvenile form) to 0.9 mm (probably megalospheric form).

HOLOTYPE: GSM 58748, Pl. LXXIX, fig. 16 a-d.

The specimen is from a core sample at 7,093 ft in Port Campbell No. 2.

This is a microspheric specimen. The proloculus and the 4 coiled chambers are prominent. There are 4 pairs of biserial chambers and an unpaired terminal chamber. The test is 0.8 mm long, 0.25 mm thick, 0.54 mm maximum width, and 0.32 mm wide in the coiled portion.

SUPPLEMENTARY SPECIMEN A: GSM 58804, Pl. LXXXV, fig. 4.

The specimen is from a rotary cutting sample at 5,540-49 ft in Port Campbell No. 1.

A longitudinal section of a specimen from the same sample and similar in form to the Holotype. The section reveals a circular proloculus around which 4 chambers are arranged in half a whorl before biserially arranged chambers are added. A dark lining is noted on the inside of all chambers; this is most pronounced in the proloculus.

The specimen is 0.73 mm long, 0.51 in maximum width, and 0.3 mm wide in the coiled portion with a proloculus of 0.1 mm in diameter.

SUPPLEMENTARY SPECIMEN B: GSM 58805, Pl. LXXXV, fig. 5.

The specimen is from a rotary cutting sample at 5,540-49 ft in Port Campbell No. 2.

A longitudinal section reveals 12 pairs of biserially arranged chambers with an indistinct initial chamber (or chambers). No initial whorl is visible. This is a megalospheric specimen. The initial end is less rounded than in the microspheric specimens. The first 6 pairs of chambers were not visible before sectioning. The specimen is 0.85 mm long and 0.51 mm in maximum width.

SUPPLEMENTARY SPECIMEN C: GSM 58747, Pl. LXXIX, fig. 17.

The specimen is from a rotary cutting sample at 6,400-10 ft in Flaxmans No. 1.

A juvenile specimen with one pair of biserial chambers which follows 4 chambers arranged in a half-whorl around a globular proloculus. The specimen is 0.25 mm long, 0.25 mm thick, and 0.32 mm in maximum width.

DISCUSSION: The overlapping, asymmetrical terminal chamber is a characteristic feature which differentiates *T. trilobita* from similar species of *Textularia*.

In the higher part of its range, the tests of *T. trilobita* become smaller, but the asymmetrical terminal chamber is retained.

As the microspheric test is reminiscent in shape to the thorax and pygidium of many trilobites, the name *T. trilobita* has been given to this species.

DISTRIBUTION: This species is confined to the upper part of Zonule B. At the top of Zonule B it is replaced by *T. semicomplanata*.

### Genus *Dorothia* Plummer 1931

#### *Dorothia conulus* (Reuss)

(Pl. LXXX, fig. 3)

- 1845 *Textularia conulus* Reuss, *Verstein. böhm. Kreide* 1: 34, Pl. 8, fig. 59; Pl. 13, fig. 75.  
 1937 *Dorothia conula* (Reuss), Cushman, *Spec. Publ. Cushman Lab.* 8: 76, Pl. 8, fig. 11-17 (with synonymy).  
 1946 *Dorothia conula* (Reuss), Cushman, *Prof. Pap. U.S. Geol. Surv.* 206: 44-45, Pl. 12, fig. 12-14.  
 1954 *Dorothia conulus* (Reuss), Frizzell, *Rep. Inv. Univ. Texas econ. Geol.* 22: 75, Pl. 6, fig. 21.

The arenaceous test is short and stout; maximum width often equals the length. The test tapers and is conical but is compressed so that the transverse section is ovoid. The earliest whorl has 5 chambers but rapidly becomes triserial and then distinctly biserial. The few biserial chambers (2-3 pairs) are inflated. The later sutures are distinctly depressed and straight. The walls are composed of cemented fine grained quartz with an occasional coarser grain. The aperture is a low opening along the inner margin of the terminal chamber. The position of the aperture is marked by a notch in the terminal face. The length of specimens ranges from 0.37 mm to 0.42 mm; the thickness of all specimens is 0.3 mm. The width is not proportional to length. The largest specimen has a length of 0.42 mm and a width of 0.34 mm, while in the smallest specimen both the length and width = 0.37 mm. The thickness of all specimens is 0.3 mm.

DISCUSSION: The specimens are typical of the American material.

DISTRIBUTION: Found only in core samples from 4,974 ft to 4,993 ft in Flaxmans No. 1 Well. From the Senonian of North America and probably from the Senonian of Europe.

FIGURED SPECIMEN: Pl. LXXX, fig. 3—GSM 58698 from a core at 4,983 ft in Flaxmans No. 1.

#### *Dorothia filiformis* (Berthelin)

(Pl. LXXX, fig. 4)

- 1880 *Gaudryina filiformis* Berthelin, *Mem. Geol. France ser. 3* 1: 25, Pl. 1 (24), fig. 8.  
 1937 *Dorothia filiformis* (Berthelin), Cushman, *Spec. Publ. Cushman Lab.* 8: 73, Pl. 8, fig. 1, 2 (with synonymy).  
 1954 *Dorothia filiformis* (Berthelin), Bartenstein, *Senck.* 35 (1/2): 39, Pl. 1, fig. 14-15.

The finely arenaceous test is elongate, very narrow and circular in transverse section, although a large percentage of specimens are squashed. The initial end is bluntly pointed, but most of the test is parallel-sided. The earlier whorls have 5 chambers, but the number of chambers decreases rapidly with succeeding whorls. Two-thirds of the test comprises 5-7 pairs of biserial chambers. The biserial portion of the test is often somewhat twisted. The distinct, depressed sutures are horizontal

or slightly flexed back. The narrow aperture is sutural along the inner margin of the terminal chamber.

The average length of specimens is 0.5 mm with an extreme of 1 mm. The maximum thickness (not compressed) is 0.1 mm to 0.15 mm.

**DISTRIBUTION:** Very common species throughout the sequence, although irregular in frequency.

Occurs in the Lower Cretaceous of Europe and Bartenstein states that it probably ranges up to the Turonian.

**FIGURED SPECIMEN:** Pl. LXXX, fig. 4—GSM 58697 from a core at 4,652 ft in Belfast No. 4.

### Genus *Marssonella* Cushman 1933

#### *Marssonella oxycona* (Reuss)

(Pl. LXXX, fig. 5-7)

1860 *Gaudryina oxycona* Reuss, *S.B. öst, Akad. Wiss.* 40: 229, Pl. 12, fig. 3.

1937 *Marssonella oxycona* (Reuss) Cushman, *Spec. Publ. Cushman Lab.* 8: 56-59, Pl. 5, fig. 27-29; Pl. 6, fig. 1-17 (with detailed synonymy).

1960 *Marssonella oxycona* (Reuss) Moullade, *Revue de Micropal.* 3 (2): 131-3, Pl. 1, fig. 1-5 (with detailed synonymy).

Conical, fine grained, arenaceous test. At the initial end there is a distinct proloculus then a 4-chambered whorl, but the test rapidly becomes triserial and finally biserial. The sutures are distinct, being flush with the surface. The aperture is a low slit along the marginal suture of the terminal face; it is often accommodated within a curved indentation in the terminal face.

The actual shape of the conical test is a variable feature. A range of variation was noted within the Victorian sequence, and it was observed that this range was present in any sample where *Marssonella oxycona* was abundant. For the purpose of studying this variation, a core sample at 5,960 ft in Flaxmans No. 1 was selected and an exhaustive pick yielded 100 specimens. The following features were noted:

- (i) Shape of initial end: either distinctly pointed, or bluntly rounded. No intrinsic difference in initial chamber arrangement could be observed. Bartenstein & Brand (1951) attribute this primary variation to dimorphism. It is noted that none of the larger specimens (length > 0.33 mm) are initially blunt. Also, the blunt specimens rapidly obtain maximum diameter, so that the ratio of length to diameter equals or approaches 1:1.
- (ii) Form of cone: the angle of the tapering varies. It can best be expressed in terms of length to diameter, as the specimens which attain maximum diameter gradually are more conical than those which attain it quickly. Therefore, initially pointed specimens, which have a ratio of length to diameter approach in 2:1, are more conical than the initially blunt specimens where the ratio approaches 1:1.
- (iii) Flaring of terminal chamber: this is a factor which appears to contradict the above conclusions. There are a limited number of specimens which have a pointed initial end and are distinctly tapered, yet the ratio of length to maximum diameter = 1:1 and the length is well over 0.33 mm. However, these specimens do not attain maximum diameter until the terminal chamber and the width of this chamber is much greater than the width of the preceding chambers, as can be seen in Pl. LXXX, fig. 7.

As already mentioned, these variants intergrade in all features apart from chamber flaring. It would appear that chamber flaring is a random feature. Spec-



mens which exhibit this feature are not comparable with *Textularia trochus* d'Orb, in which the width of the chambers increase gradually and proportionally: Minimum length = 0.2 mm; maximum length = 0.75 mm.

**DISTRIBUTION:** *Marssonella oxycona* is distributed throughout the Victorian sequence, although it is rare or absent high in the sequence. Even though there is a world-wide break in the distribution of *M. oxycona* during the Aptian, Moullade (1960, p. 131-3) concludes that the forms on either side of this break are analagous and thus, *M. oxycona* is present in both the Lower and Upper Cretaceous.

**FIGURED SPECIMENS:** Pl. LXXX, fig. 5—GSM 58725 from a core at 5,950 ft in Flaxmans No. 1; fig. 6—GSM 58724 from a cutting sample at 6,010 to 6,017 ft in Port Campbell No. 2; fig. 7—GSM 58723 from a core at 5,950 ft in Flaxmans No. 1.

### Genus *Cornuspira* Schultze 1854

#### *Cornuspira involvens* (Reuss)

(Pl. LXXX, fig. 8)

1850 *Operculina involvens* Reuss, *K. Akad. Wiss. Wien. Math-Nat.*, Bd. 1: 370, Pl. 46, fig. 20.

1891 *Cornuspira involvens* (Reuss), Chapman, *J. Roy. Micro. Soc.* 11: 574, Pl. 9, fig. 12.

1958 *Cornuspira involvens* (Reuss), Pokorny, *Mikropalaontologie*, Berlin, 1: 249, Fig. 210.

The unornamented test is a long planispirally coiled tube of imperforate calcareous material of a porcellanous appearance, orange in colour. Both surfaces are concave. The tube gradually increases in diameter and the whorls slightly overlap the succeeding whorls. The proloculus is missing in all Victorian specimens. The aperture is a simple opening at the end of the tube where there is some thickening of the wall.

The diameter of specimens ranges from 0.4 mm to 0.65 mm, thickness from 0.1 mm to 0.15 mm.

**DISCUSSION:** The Victorian specimens are typical of the Lower Cretaceous specimens from Europe. In test shape, this species resembles *Operculina cretacea* Reuss 1845 (*non* Reuss 1862). Cushman (1934) places this species within the genus *Ammodiscus* as its walls are composed of arenaceous material.

**DISTRIBUTION:** Occurs with *Quinqueloculina* spp., mainly in Zonule A. Reported only from the Lower Cretaceous of Europe.

**FIGURED SPECIMEN:** Pl. LXXX, fig. 8—GSM 58694 from a core sample at 5,025 ft in Port Campbell No. 1.

#### *Cornuspira subprimitiva* Bartenstein & Brand

(Pl. LXXX, fig. 9-10)

1951 *Cornuspira?* *primitiva* Bartenstein & Brand, *Senckenb. Naturf. Ges.* 485: 279, Pl. 4, fig. 90.

1952 *Cornuspira?* *subprimitiva* Bartenstein & Brand, *Thalman, J. Paleont.* 26 (6): 972.

The planispiral discoidal test has calcareous imperforate walls of granular structure and the surface is roughened. One face is flat while the other is slightly convex and the periphery is rounded. There is a globular proloculus followed by a tube-like second chamber of 2-3 volutions. Simple aperture at end of tube.

Diameter of specimens ranges from 0.22 mm to 0.26 mm; thickness is constant at 0.1 mm.

**DISCUSSION:** The roughened surface veils the chamber structure, so it was found necessary to immerse one specimen in weak acid. The Victorian *C. sub-*

*primitiva* agrees with the generic diagnosis of *Cornuspira*, as well as with the type description and figures of *C. ? subprimitiva* Bartenstein & Brand.

**DISTRIBUTION:** Rarer than *C. involvens* with which it is associated in the sequence. Reported from the Lower Cretaceous.

**FIGURED SPECIMENS:** Pl. LXXX, fig. 9 a-b—GSM 58695 from a core sample at 4,757 ft in Port Campbell No. 1; fig. 10—GSM 58693 from a core sample at 4,757 ft in Port Campbell No. 1.

### Genus *Quinqueloculina* d'Orbigny 1826

#### *Quinqueloculina* sp.

(Pl. LXXX, fig. 11)

The small angular test is a little greater in length than in width and is triangular in transverse section with flat faces and rounded peripheries. The terminal aperture does not protrude, is rounded, and contains a definite tooth plate. The test is of imperforate calcareous material, porcellaneous in appearance and orange in colour, but some specimens have fine grained arenaceous material incorporated in the test.

Length of specimens ranges from 0.33 mm to 0.5 mm, maximum thickness from 0.25 to 0.33 mm.

**DISCUSSION:** This species of *Quinqueloculina* lacks distinctive characters to the point of being unclassifiable on a specific level. Similar to some living *Quinqueloculina*.

**DISTRIBUTION:** Occurs mainly in Zonule A, abundant in some samples (e.g. core at 4,757 ft in Port Campbell No. 1), absent in others. Its distribution appears to be facies controlled.

**FIGURED SPECIMEN:** Pl. LXXX, fig. 11—GSM 58737 from a core at 4,757 ft in Port Campbell No. 1.

### Genus *Nodosaria* Lamarck 1812

#### *Nodosaria obscura* Reuss

(Pl. LXXX, fig. 12-13)

1845 *Nodosaria obscura* Reuss, Verstein, *bohm. Kreide*. 1: 26, Pl. 13, fig. 7-9.

1936 *Nodosaria obscura* Reuss, Brotzen, *Sver. geol. Unders. ser. C* 396: 84, Pl. 5, fig. 24-25; Fig. 26-27 (with synonymy).

1946 *Nodosaria obscura* Reuss, Cushman, *Prof. Pap. U.S. Geol. Surv.* 206: 73, Pl. 26, fig. 15, 16.

1960 *Nodosaria obscura* Reuss, Belford, *Bur. Min. Resourc. Aust. Bull.* 57: 36-38, Pl. 11, fig. 1-3; Fig. 1 (with synonymy).

The elongate test comprises a linear series of chambers. The test is widest in the terminal chamber and tapers towards the initial end where it is distinctly pointed. In transverse section the chambers are circular. The chambers progressively increase in length, although this is not a constant feature in the earlier chambers of some specimens. The external test wall is ornamented by 8-10 longitudinal costae which are continuous along the whole length of the test. The costae coalesce at the terminal end where the aperture is simple and surrounded by a distinct collar.

The few Victorian specimens of this species fall into two groups, namely:

- (i) A broad 4-chambered form, the length is twice the width, length (mm) to width (mm) in 4 specimens being—0.4 : 0.22, 0.38 : 0.2, 0.35 : 0.19, and 0.28 : 0.14. Typical specimen of this form is illustrated in Pl. LXXX, fig. 13.

- (ii) A slender 7-9 chambered form, the proportion of length to width is 5 : 2, these dimensions (mm) in 4 specimens being 0.54 : 0.21, 0.52 : 0.19, 0.51 : 0.19, and 0.47 : 0.18. Typical specimen of this form is illustrated in Pl. LXXX, fig. 12.

DISCUSSION: Both Brotzen (1936) and Bedford (1960) discuss variation within this species and divide their material into a series of types. With so little material available, to assign the described specimens to any of these types is difficult, although the broad form appears to fit Brotzen's Type III. The clear-cut differentiation between the two forms may well indicate megalospheric and microspheric generations, but more material is required to substantiate this.

DISTRIBUTION: Rare in the Victorian sequence. A typically Senonian species from Europe, North America, and Western Australia.

FIGURED SPECIMENS: Pl. LXXX, fig. 12—GSM 58732 from a core at 5,950 ft in Flaxmans No. 1; fig. 13—GSM 58731 from a core at 4,757 ft in Port Campbell No. 1.

***Nodosaria cf. obscura* Reuss**

(Pl. LXXX, fig. 14)

Similar to the described 7-9 chambered specimens of *N. obscura*, except that the 8 longitudinal costae bifurcate at the beginning of the last chamber. Only one specimen has been found but its ornamentation is distinctive enough to separate it from the other specimens of this species. No reference to costae bifurcation in *N. obscura* can be found in the literature.

OCCURRENCE: The single specimen GSM 58730 is from a core at 4,710 ft in Port Campbell No. 1 Well.

***Nodosaria alternistriata* Morrow**

(Pl. LXXX, fig. 15-16)

1934 *Nodosaria alternistriata* Morrow, *J. Paleont.* 8: 190, Pl. 29, fig. 1.

1946 *Nodosaria alternistriata* Morrow, Cushman, *Prof. Pap. U.S. Geol. Surv.* 206: 71, Pl. 26, fig. 3, 4.

The test consists of a linear series of 6-9 cylindrical chambers. The test is circular in transverse section. Progressive increase is not a constant feature in chamber width and height, as the last chamber may not be as wide as the preceding one, and often a long narrow chamber is between the shorter, broader ones. Sutures are depressed, earlier sutures often obscured by surface ornamentation. The external surface is covered by numerous costae (16-20) which vary in intensity. The costae reach almost to the distinct collar which surrounds the aperture.

The lengths of specimens vary from 0.6 mm to 0.8 mm, maximum width from 0.25 mm to 0.3 mm.

DISCUSSION: Whether *N. alternistriata* is a synonym of *N. fusula* Reuss 1872 is not considered, although it is implied by Cushman (1946). The Victorian specimens agree in all features with the description of the former species but differ from the latter in not having a drawn out apertural neck.

DISTRIBUTION: Fairly rare in the Victorian sequence. From the lower Senonian in North America.

FIGURED SPECIMENS: Pl. LXXX, fig. 15—GSM 58727 from a core at 5,025 ft in Port Campbell No. 1; fig. 16—GSM 58726 from a core at 5,950 ft in Flaxmans No. 1.



**Nodosaria navarroana** Cushman

(Pl. LXXX, fig. 17-18)

- 1937 *Nodosaria navarroana* Cushman, *Cushman Lab. Contr.* 13 (4): Pl. 15, fig. 11.  
 1946 *Nodosaria navarroana* Cushman, Cushman, *Prof. Pap. U.S. Geol. Surv.* 206: 73, Pl. 26, fig. 23-24.  
 1954 *Nodosaria navarroana* Cushman, Frizzell, *Rep. Inv. Univ. Texas Bur. econ. Geol.* 22: 62, Pl. 2, fig. 20.

The elongate test tapers at the initial end but the final 3-4 chambers are of the same diameter. In transverse section the test is 5-sided with each side slightly concave. The angles of the test are marked by 5 longitudinal costae which extend from the initial end to the apertural collar where they coalesce. Each of the 7-8 chambers partially embrace the preceding chamber, and the increase in chamber length is not always progressive. The distinct sutures are straight to slightly curved but form a backwardly directed 'V' along the costae. The terminal end tapers up to the simple aperture which is surrounded by a definite collar.

The length of specimens ranges from 0.3 mm to 0.5 mm, while the maximum diameter ranges from 0.11 mm to 0.2 mm.

DISCUSSION: The few Victorian specimens assignable to this species show some variation in degree of ornamentation and the degree of initial tapering. Despite the fact that the type description of *N. navarroana* states that 4 longitudinal costae are present, the type figure clearly shows 5 costae. *N. orthopleura* is a very similar species but is much larger (Holotype = 3 mm in length).

DISTRIBUTION: Very rare, found only in Zonule A. From the Campanian and probably Maastrichtian in North America.

FIGURED SPECIMENS: Pl. LXXX, fig. 17—GSM 58729 from a core at 4,652 ft in Belfast No. 4; fig. 18—GSM 58728 from a core at 5,950 ft in Flaxmans No. 1.

**Genus Dentalina** d'Orbigny 1826**Dentalina cf. intrasegma** (Carsey)

(Pl. LXXX, fig. 19)

- 1926 *Nodosaria intrasegma* Carsey, *Univ. Texas Bull.* 2612: 33, Pl. 4, fig. 10.  
 1938 *Dentalina solvata* Cushman, *Contr. Cushman Lab.* 14 (2): 39-40, Pl. 6, fig. 9-14.  
 1946 *Dentalina solvata* Cushman, Cushman, *Prof. Pap. U.S. Geol. Surv.* 206: 68, Pl. 24, fig. 13-17, 22.  
 1954 *Dentalina intrasegma* (Carsey), Frizzell, *Rep. Inv. Univ. Texas Bur. econ. Geol.* 22: 88, Pl. 9, fig. 52-54.

None of the available specimens is complete; the initial ends are missing and the terminal chambers may not be present. The test is a linear series of slender, elongate, bead-like chambers which increase progressively in length and are circular in transverse section. The test is indented at the sutures which are thickened. The surface of some of the larger chambers is smooth, while on others there are fine longitudinal costae. These costae persist across all the sutures. The simple aperture is terminal and central and appears to have been on a neck.

The length of the largest specimen (figured specimen: 4 chambers intact) is 0.68 mm with a maximum width of 0.15 mm.

DISCUSSION: The fragmentary nature of the specimens does not permit a confident determination. However, the persistence of the costae over the sutures is a specific character of *D. intrasegma*.

**DISTRIBUTION:** Fairly rare, but difficult to identify positively. *D. introsegma* is described from the Senonian of North America.

**FIGURED SPECIMEN:** Pl. LXXX, fig. 19—GSM 58696 from a core at 5,025 ft in Port Campbell No. 1.

### Genus *Lenticulina* Lamarck 1804

Representatives of the genus *Lenticulina* are a fairly constant feature of the fauna, though by no means abundant. Intergradation has made specific determinations difficult. Only 3 distinct species have been described, 2 of which are regarded to be of local stratigraphic importance. The undescribed forms of this genus are listed as *Lenticulina* spp. in the distribution charts.

Closely related genera to *Lenticulina* have been erected, but have been relegated to sub-generic status by some authors, including Pokorný (1958, p. 277-9). This procedure has been followed in the belief that *Marginulinopsis* Silvestra 1904, *Saracenaria* DeFrance 1824, *Robulus* Montfort 1808, etc. are not generically distinct from *Lenticulina*.

### Subgenus *Robulus* Montfort 1808

#### *Lenticulina* (*Robulus*) *navarroensis* (Plummer)

(Pl. LXXXI, fig. 1-3)

- 1927 *Cristellaria navarroensis* Plummer, *Texas Univ. Bull.* 2644: 39, fig. 4.
- 1946 *Robulus navarroensis* (Plummer) Cushman, *Prof. Pap. U.S. Geol. Surv.* 206: 51-2, Pl. 16, fig. 6-8 (with synonymy).
- 1954 *Robulus navarroensis* (Plummer) var. *navarroensis* Frizzell, *Rep. Inv. Univ. Texas Bur. econ. Geol.* 22: 81, Pl. 8, fig. 6.
- 1936 *Robulus navarroensis* (Plummer) var. *extruatus* Cushman, *Contr. Cushman Lab.* 14: 31, Pl. 5, fig. 1.
- 1946 *Robulus navarroensis* (Plummer) var. *extruatus* Cushman, Cushman, *Prof. Pap. U.S. Geol. Surv.* 206: 52, Pl. 16, fig. 9, 10; pl. 17, fig. 2 (with synonymy).
- 1954 *Robulus navarroensis* (Plummer) var. *extruatus* Cushman, Frizzell, *Rep. Inv. Texas Bur. econ. Geol.* 22: 81, Pl. 8, fig. 6.

A test of 7 to 12 chambers around a distinct central boss. The sutures are limbate, slightly to distinctly raised and fuse with the central boss. The periphery has a broad thin keel.

This is the largest species in the Victorian sequence as it obtains a maximum diameter of 2.2 mm. The maximum thickness (thickness of central boss) is one-third of the diameter.

**DISCUSSION:** Typical of the American representatives of this species, although some Victorian specimens have as few as 7 chambers, while the American species have from 10 to 12 chambers. It is impossible to separate the specimens with distinctly raised sutures from those with slightly raised sutures. For this reason, *R. navarroensis* var. *extruatus* is not recognized.

**DISTRIBUTION:** Rarely and sporadically distributed throughout the sequence. Occurs in the upper Senonian in North America.

**FIGURED SPECIMENS:** Pl. LXXXI, fig. 1—GSM 58738 from a core at 5,025 ft in Port Campbell No. 1; fig. 2—GSM 58739 from a core at 5,910 ft in Port Campbell No. 2; fig. 3—GSM 58740 from a cutting sample at 5,400-10 ft in Port Campbell No. 1.

Subgenus **Marginulinopsis** Silvestri 1904**Lenticulina (Marginulinopsis) jarvisi** (Cushman)

(Pl. LXXXI, fig. 6)

1938 *Marginulina jarvisi* Cushman, *Contr. Cushman Lab.* 14: 35, Pl. 5, fig. 17-18.1946 *Marginulina jarvisi* Cushman, Cushman, *Prof. Pap. U.S. Geol. Surv.* 207: 63, fig. 18-20.

The smooth walled elongate test is ovoid in cross section and has a rounded periphery. The early portion is coiled with 4 chambers and there are 3-5 linear chambers. All curved sutures are distinct; the earlier ones are limbate while the later are narrower but depressed. The radiate aperture is peripheral. The linear chambers are parallel-sided, except in the terminal chamber where the terminal face slopes steeply for two-thirds of the chamber length. The coiled portion does not project laterally beyond the sides of the linear chambers. Maximum length is 0.9 mm, and maximum diameter is 0.35 mm.

**DISCUSSION:** The steep terminal face and limbate early sutures distinguish this species from other smooth walled members of the sub-genus.

**DISTRIBUTION:** Restricted to the bottom part of the sequence. Usually confined to Zonule B, but has been recorded several hundred feet above this Zonule. Is not an abundant form. Occurs in the Upper Cretaceous, probably upper Senonian.

**FIGURED SPECIMEN:** Pl. LXXXI, fig. 6—GSM 58722 from a core sample at 7,093 ft in Port Campbell No. 2.

**Lenticulina (Marginulinopsis) curviseppta** (Cushman & Goudkoff)

(Pl. LXXXI, fig. 4-5)

1944 *Marginulina curviseppta* Cushman & Goudkoff, *Contr. Cushman Lab. Foram. Res.* 20: 57, Pl. 9, fig. 12-13.

The roughened, elongate test has a planispirally coiled early portion which is somewhat depressed with a distinct keel. The chambers in the coiled portion are indistinct though distinct in the uncoiled portion as the sutures are depressed. The uncoiled chambers are ovoid to circular in cross section and are parallel-sided with the terminal face flat to faintly angled. The coiled portion projects laterally on one side beyond the uncoiled chamber. The test is ornamented by many distinct, longitudinal costae which extend from the coiled portion to the radiate peripheral aperture.

**DISCUSSION:** The inflated linear chambers and the complete ornamentation of the test distinguishes this species from other ornamented species of *L. (Marginulinopsis)* in the sequence.

**DISTRIBUTION:** Occurs rarely throughout the sequence, yet it is of importance as it appears high in the sequence and helps confirm the highest recognitions of Cretaceous sediment in well sequences. Upper Cretaceous, but exact range is not known.

**FIGURED SPECIMENS:** Pl. LXXXI, fig. 4—GSM 58720 from a cutting sample at 5,600 to 5,610 ft in Port Campbell No. 2; fig. 5—GSM 58721 from a cutting sample at 5,600 to 5,610 ft in Port Campbell No. 2.



Genus *Marginulina* d'Orbigny 1826*Marginulina inaequalis* Reuss

(Pl. LXXXI, fig. 7-8)

1860 *Marginulina inaequalis* Reuss, Sitzber, *Akad. Wiss. Wien.* 44: 207, Pl. 5, fig. 3.1936 *Marginulina inaequalis* Reuss, Brotzen, *Sver. Geol. Unders., Ser. C* 396: 63-4, Pl. 4, fig. 3 (with detailed synonymy).

The smooth calcareous test consists of a linear series of 5 to 6 chambers. In outline it is straight or slightly curved and is circular in transverse section. The initial end of the test is rounded with a globular transparent area which appears to be the proloculus. The chambers increase gradually in diameter so that the sides of the test are not parallel. There is little increase in the height of chambers apart from the terminal chamber which is twice as high as the preceding one. The final face slopes obliquely away from the aperture to half way down the terminal chamber. The distinct, depressed sutures slope down from the apertural side. The simple aperture with its grooved neck is on one side of the test.

Length of specimens ranges from 0.5 mm to 0.65 mm, maximum diameter of last chamber ranges from 0.15 mm to 0.22 mm.

DISTRIBUTION: Rare in the sequence. Occurs in the Lower Cretaceous and throughout the Upper Cretaceous.

FIGURED SPECIMENS: Pl. LXXXI, fig. 7—GSM 58718 from a core at 4,757 ft in Port Campbell No. 1; fig. 8—GSM 58719 from a core at 5,950 ft in Flaxmans No. 1.

Genus *Citharina* d'Orbigny 1839*Citharina geisendorferi* (Franke)

(Pl. LXXXI, fig. 10)

1928 *Vaginulina geisendorferi* Franke, *Abh. preuss. geol. Landesanst.* N.S. 11: 80, Pl. 7, fig. 18.1954 *Citharina geisendorferi* (Franke), Frizzell, *Rep. Inv. Univ. Texas Bur. econ. Geol.* 22: 94, Pl. 11, fig. 5.1960 *Citharina geisendorferi* (Franke), Belford, *Bur. Min. Resour. Aust. Bull.* 57: 40, Pl. 11, fig. 14-15.

The smooth calcareous test consists of 2 ovoid chambers with low convex faces. The base of the proloculus is rounded but the two sides are parallel; in the later chamber the apertural side remains straight while the other side converges with it at the aperture. The suture is broad and depressed and is higher on the apertural side. The periphery of the test is bicarinate throughout. The terminal aperture is a simple protruding tube covered by the clear peripheral material.

The dimensions of the 4 available specimens approximate to those of the figured specimen which are: length = 0.45 mm, maximum width = 0.2 mm, and maximum thickness (= thickness of proloculus) = 0.16 mm.

DISTRIBUTION: Very rare. Occurs in the Turonian of Europe, but Belford records it from lower Senonian of Western Australia.

FIGURED SPECIMEN: Pl. LXXXI, fig. 10—GSM 58687 from a core at 4,757 ft in Port Campbell No. 1.

*Citharina whangaia* (Finlay)

(Pl. LXXXI, fig. 9)

1939 *Planularia whangaia* Finlay, *Trans. Roy. Soc. N.Z.* 69 (3): 317, Pl. 26, g. 63-65.

The test is triangular in outline and wedge-shaped in side view, as each chamber is higher aperturally than initially and the chamber height increases progressively.

The proloculus is elongate, but forms a curve in the base of the straight apertural side of the test. 6-9 chambers are present. The periphery of the ultimate chamber is concave with a ridge on both edges. Fine longitudinal costae are present on all chambers including the proloculus, but these costae do not appear to cross the prominent sutures.

The length of specimens ranges from 0.55 mm to 0.88 mm.

DISCUSSION: Although Finlay does not describe variation in chamber height (both individually and collectively), the Victorian specimens exhibit close similarity to *C. whangaia* and the ornamentation pattern is identical. Similarities are also noted with the Western Australian and Victorian Paleocene species *C. subplumoides* (Parr), but in this species the sutures are not so distinct and the ornamentation crosses them.

None of the author's specimens was complete, so Dr Glaessner kindly lent the few specimens from his collection.

DISTRIBUTION: Very rare. Probably confined to Zonule A. This species was described from the New Zealand Campanian.

FIGURED SPECIMEN: Pl. LXXXI, fig. 9—GSM 58688 from a core sample 5,910 ft in Port Campbell No. 2.

### Genus *Frondicularia* DeFrance 1826

#### *Frondicularia* cf. *mucronata* Reuss

(Pl. LXXXI, fig. 11-12)

- 1845 *Frondicularia mucronata* Reuss, *Verstein bohln. Kreide* 1: 31, Pl. 13, fig. 43-44.  
1939 *Frondicularia mucronata* Reuss, Finlay, *Trans. Roy. Soc. N.Z.* 69 (3): 316, Pl. 26, fig. 58.  
1946 *Frondicularia mucronata* Reuss, Cushman, *Prof. Pap. Geol. Surv.* 206: 87, Pl. 34, fig. 14-17.  
1954 *Frondicularia mucronata* Reuss, Frizzell, *Rep. Inv. Univ. Texas Bur. econ. Geol.* 22: 99, Pl. 12, fig. 36-37.  
1957 *Frondicularia mucronata* Reuss, Hofker, *Beih. geol. Jb.* 27: 153 (reference only).  
1960 *Frondicularia mucronata* Reuss, Belford, *Bur. Min. Resur. Aust. Bull.* 57: 46, Pl. 12, fig. 10-11 (with detailed synonymy).

No complete tests of this species were isolated, so only fragments can be described. All the fragments are of smooth, calcareous, thick walled tests which are broad, though compressed laterally.

- (i) Initial end: Has a very elongate proloculus with a raised central ridge, and protrudes as a basal spine. The proloculus is in part parallel-sided, but the sides then converge towards the terminal end. Each of the 7 embracing chambers appear to have the same outline as the proloculus. The sutures are clear but not depressed. There is a peripheral flange of transparent test material which is the same thickness as the chambers.
- (ii) Apertural end: Each chamber converges to a parallel-sided apertural neck which has a simple aperture.

In these fragments the maximum width is 0.6 mm and the length of the proloculus is 0.3 mm. The length of a complete test is expected to be 1.5 mm approximately.

DISCUSSION: The elongate, ridged proloculus and the partial parallelism of chamber outlines are characters of *F. guestphalica* Reuss and *F. mucronata* Reuss. The chamber walls of the former species are ornamented with grooves, which is not a feature of the Victorian material. Close affinities with *F. mucronata* are evident,

but a precise specific determination is not justified with the fragmentary material available.

**DISTRIBUTION:** Very rare and occurs only in Zonule A. A Senonian form, though Hofker mentions it as a Turonian species.

**FIGURED SPECIMENS:** Pl. LXXXI, fig. 11—GSM 58699 from a cutting sample at 6,010 to 6,017 ft in Port Campbell No. 2; fig. 12—GSM 58700 from a cutting sample at 6,010 to 6,017 ft in Port Campbell No. 2.

### ***Frondicularia* sp.**

(Pl. LXXXI, fig. 13)

The single specimen is broken at the terminal end. The elongate operculus is inflated with a single, longitudinal costac on both sides and a terminal spine. The only other chamber embraces most of the proloculus though not its base. This second chamber is slightly convex but not as thick as the proloculus. The outer margin is bi-carinate while the inner margin is marked by a distinct limbate suture. The test tapers towards the apertural end with the greatest width at a third of the length from the terminal spine.

The length of the specimen = 0.3 mm, maximum width = 0.18 mm, maximum thickness (= thickness of proloculus) = 0.11 mm.

**DISCUSSION:** The incompleteness of this specimen makes specific identity difficult, especially as the mode of chamber addition is not known. The elongate, costate proloculus with terminal spine is similar to specimens here described as *F. cf. mucronata* Reuss. However, both chambers of this specimen are inflated. Also, it is suspected that chamber addition is of elongate and not lateral pattern as in *F. mucronata*. No other described species shows the essential features of this specimen which may represent a new species.

**DISTRIBUTION:** The single specimen GSM 58701 was found in a core sample from 4,652 ft in Belfast No. 4.

### **Genus *Globulina* d'Orbigny 1826**

#### ***Globulina lacrima* Reuss**

(Pl. LXXXI, fig. 14)

- 1845 *Polymorphina* (*Globulina*) *lacrima* Reuss, *Verstein. bohm. Kreide* 1: 20, Pl. 12, fig. 6; Pl. 13, fig. 83.
- 1946 *Globulina lacrima* Reuss, Cushman, *Prof. Pap. U.S. Geol. Surv.* 206: 96, Pl. 40, fig. 8-10 (with detailed synonymy).
- 1957 *Globulina lacrima* Reuss, Hofker, *Beih. geol. Jb.* 27: 107-8, Fig. 212-3 (with detailed synonymy).

The smooth, finely perforate test is subglobular with a broadly rounded base. Each chamber has a hemispherical outline on the test surface and partially overlaps the preceding chambers. 4 chambers are visible, the earliest chamber is only visible at the base, but the later 3 extend to the base. The curved sutures are distinct and depressed. The terminal chamber is produced up to the radiate aperture. The length of specimens is from 0.35 mm to 0.4 mm, the maximum width from 0.3 to 0.35 mm, and maximum thickness from 0.25 mm to 0.3 mm.

**DISCUSSION:** This form may be referable to *G. lacrima subsphaerica* (Berthelin), as the maximum width is a little greater than the maximum thickness.

**DISTRIBUTION:** Found rarely in cores from Zonule A. This is a wide ranging species.



FIGURED SPECIMEN: Pl. LXXXI, fig. 4—GSM 58703 from a core at 5,900 ft in Port Campbell No. 2.

Genus *Praebulimina* Hofker 1953

*Praebulimina ovulum* (Reuss)

(Pl. LXXXI, fig. 15)

- 1844 *Bulimina ovulum* Reuss (non *ovula* d'Orbigny), *Geog. Skizzen Bohm.* 2: 215.  
 1934 *Bulimina reussi* Morrow, new name. Morrow, *J. Paleont.* 8: 195, Pl. 29, fig. 12.  
 1946 *Bulimina reussi* Morrow, Cushman, *Prof. Pap. U.S. Geol. Surv.* 206: 120, Pl. 51, fig. 1-5 (with synonymy).  
 1951 *Praebulimina ovula* (Reuss), Hofker, *Siboga Exped., Mongr. 4a, Leiden*, p. 123, Fig. 73, 74.  
 1954 *Bulimina ovulum* Reuss ver. *ovulum* Reuss, Frizzell, *Rep. Inv. Univ. Texas Bur. econ. Geol.* 22: 115, Pl. 17, fig. 2.  
 1957 *Praebulimina ovulum* (Reuss), Hofker, *Beih. Geol. Jb.* 27: 184.  
 1960 *Praebulimina ovulum* (Reuss), Belford, *Bur. Min. Resour. Aust. Bull.* 57: 64-5, Pl. 16, fig. 7-9 (with synonymy).

The small, smooth walled, finely perforate test is globular being sub-circular in transverse section. The chambers rapidly increase in size so that the test tapers to a rounded initial end. Initial chambers are indistinct but later ones are triserially arranged. The sutures are narrow and flush with surface. The virguline aperture is sub-terminal.

Maximum length of specimens ranges from 0.15 mm to 0.2 mm with maximum width from 0.1 mm to 0.15 mm.

DISCUSSION: The belief that *B. ovulum* Reuss 1844 was a homonym of *B. ovula* d'Orbigny 1839 led to the erection of *B. reussi* Morrow 1934 for Reuss's species. But subsequent authors show that *B. ovulum* Reuss is valid, and that this species is taxonomically distinct from *B. ovula* d'Orbigny (refer Belford 1960, p. 64).

DISTRIBUTION: The distribution of this species is sporadic, even within the one core. Appears to be confined to the dark mudstones of Zonulc A. Widely distributed in Santonian and Campanian deposits.

FIGURED SPECIMEN: Pl. LXXXI, fig. 15—GSM 58736 from a core at 4,757 ft in Port Campbell No. 1.

Genus *Buliminella* Cushman 1911

*Buliminella* cf. *parvula* Brotzen

(Pl. LXXXI, fig. 16)

- 1948 *Buliminella parvula* Brotzen, *Sver. Geol. Unders. C.* 443: 57, Pl. 10, fig. 3, 4.  
 1957 *Praebulimina parvula* (Brotzen), Hofker, *Beih. geol. Jb.* 27: 193, Fig. 238.

The very small test is  $1\frac{1}{2}$  times as long as broad, though some specimens are more elongate. There are at least 3 whorls with 4 chambers to the whorl. The earlier chambers are indistinct. The later sutures are narrow and slightly depressed. The initial end is bluntly rounded. The loop-shaped aperture extends from the final suture into the final chamber face. The test is finely perforate and smooth.

The dimensions of specimens range from 0.13 mm long and 0.07 mm wide, to 0.23 mm long and 0.1 mm wide.

DISCUSSION: The Victorian material is more elongate than typical specimens of *B. parvula*, but otherwise is closely comparable. Some specimens from Dr Glaessner's material are markedly elongate and are regarded by him as having close affinities to *B. westraliensis* Parr from the Australian Paleocene. The author believes that

there are forms (within the one sample) which are intermediary between that considered as *B. cf. parvula* and *B. aff. westraliensis*. At present, all specimens are assigned to *B. cf. parvula*, although further material may clearly show a new species should be erected.

DISTRIBUTION: Sporadic, found only in Zonule A. *B. parvula* occurs in the European Maastrichtian.

FIGURED SPECIMEN: Pl. LXXXI, fig. 16—GSM 58679 from a core at 4,652 ft in Belfast No. 4 Bore.

Genus *Allomorphina* Reuss 1850

*Allomorphina pyriformis* sp. nov.

(Pl. LXXXII, fig. 5)

DESCRIPTION OF HOLOTYPE: GSM 58673, Pl. LXXXII, fig. 5.

The smooth walled test is pear shaped. It has a depressed spire on one side and is bi-convex with a rounded periphery. 4 whorls are visible on the spiral side with 3 chambers to the whorl. The terminal chamber of each whorl is distinctly elongate, its length being  $\frac{2}{3}$  of the total length of the whorl. The sutures are distinct though only slightly depressed. Only 3 chambers are visible on the umbilical side. There is a straight marginal suture between the terminal chamber and both the preceding chambers. The apertural slit occupies  $\frac{2}{3}$  of this suture but does not reach the periphery. There is a broad apertural lip which slightly overlaps both the preceding chambers.

The test is 0.5 mm long, 0.4 mm in maximum width, and 0.33 mm in maximum height. (Both the maximum width and height are those of the first 2 chambers of the last whorl, as the terminal chamber tapers away from the marginal suture.)

The specimen is from a core sample at 4,974 ft in Flaxmans No. 1 Well.

UNFIGURED SPECIMENS: All other specimens are poorly preserved. The pear-shape of the whorls and the straight marginal suture on the ventral side are constant features. The length of specimens ranges from 0.25 mm to 0.53 mm, while the width from 0.25 mm to 0.42 mm.

DISCUSSION: The straight marginal suture with the apertural lip overlapping both preceding chambers, makes this species distinct from other Cretaceous *Allomorphina*. But these features are exhibited in the Paleocene form *A. halli* Jennings 1936 and *A. paleocenica* Cushman 1948. Neither of these species has such radially elongate and tapering terminal chambers.

The specific name of *A. pyriformis* alludes to its pear-shaped whorls.

DISTRIBUTION: This is an extremely rare species.

Genus *Pallaimorphina* Tappan 1957

*Pallaimorphina heliciformis* sp. nov.

(Pl. LXXXII, fig. 6-7)

DESCRIPTION OF HOLOTYPE: GSM 58734, Pl. LXXXII, fig. 6.

The small, finely perforate test is trochospiral with the spiral side being slightly turreted and the umbilical side flattened. There are 2 whorls visible on the spiral side with 5 chambers in the outer whorl. The chambers increase gradually in both height and length, so there is little inflation and none of the chambers is radially elongate. The sutures are curved and depressed on the spiral side. On the umbilical

side there is only one whorl visible which has straight sutures radiating out from the shallow umbilical hollow. The aperture is a small sutural slit extending from one side of the umbilicus to the periphery, bordered above by a narrow lip. The lip does not extend over the umbilical area.

The maximum diameter is 0.19 mm, the maximum height of the test is 0.1 mm, and the height of the last chamber is 0.09 mm.

The specimen is from a core sample at 5025 ft in Port Campbell No. 1 Well.

DESCRIPTION OF SUPPLEMENTARY SPECIMEN: GSM 58733, Pl. LXXXII, fig. 7.

The compressed test may be a little distorted. General features characteristic of the holotype.

Maximum diameter is 0.2 mm, the maximum height is 0.11 mm, and the height of the last chamber is 0.1 mm.

The specimen is from a core sample at 4,710 ft in Port Campbell No. 1 Well.

The maximum diameters of specimens range from 0.15 mm to 0.25 mm.

DISCUSSION: The chamber shape and especially the apertural features make this species generically distinct from *Quadromorphina* Finlay and *Allomorphina* Reuss. This species is generically similar to the genotype of *Pallaimorphina*, *P. ruckerae* Tappan 1957, but differs in that it is more noticeably trochospiral, and that the aperture and the lip extend to the periphery.

The specific name of *P. heliciformis* refers to the gastropod like shape of the test in side view, with the terminal chamber resembling a protruding 'foot' of a gastropod.

DISTRIBUTION: Confined to Zonule A. This is the highest reported occurrence of this genus, which has been recorded from the Albion to the Turonian.

#### Genus *Stilostomella* Guppy 1894

##### *Stilostomella alexanderi* (Cushman)

(Pl. LXXXII, fig. 8)

1936 *Ellipsonodosaria alexanderi* Cushman, *Contr. Cushman Lab.* 12 (3): 52, Pl. 9, fig. 6-9.

1946 *Ellipsonodosaria alexanderi* Cushman Cushman, *Prof. Pap. U.S. Geol. Surv.* 206: 135, Pl. 56, fig. 12-15.

1954 *Stilostomella alexanderi* Cushman var. *alexanderi* Cushman, Frizzell, *Univ. Texas Bur. econ. Geol. Rep.* 22, Pl. 18, fig. 13-14 (amended from *E. alexanderi* on p. 121).

An elongate series of slightly inflated chambers. The sutures are depressed. The test is ornamented by backwardly directed pointed spines which originate from a ring on each chamber. The apertural area is missing.

Length of specimen = 0.75 mm; maximum diameter = 0.15 mm.

DISCUSSION: This specimen has the distinctive ornamentation of *S. alexanderi*.

DISTRIBUTION: One specimen only GSM 58752 from a core sample at 4,652 ft in Belfast No. 4.

This species is reported from the upper Senonian of North America.

#### Genus *Pleurostomella* Reuss 1860

##### *Pleurostomella subnodosa* Reuss

(Pl. LXXXII, fig. 9)

1860 *Pleurostomella subnodosa* Reuss, *S.B. öst, Akad. Wiss. Wien.* 40: 204, Pl. 8, fig. 2.

1946 *Pleurostomella subnodosa* Reuss, Cushman, *Prof. Pap. U.S. Geol. Surv.* 206: 132, Pl. 55, fig. 1-9 (with synonymy).

1954 *Pleurostomella subnodosa* Reuss, Frizzell, *Rep. Inv. Univ. Texas, Bur. econ. Geol.* 22: 120, Pl. 18, fig. 6.

1960 *Pleurostomella subnodosa* Reuss, Belford, *Bur. Min. Resour. Aust.* 57: 70, Pl. 19, fig. 3-5 (with synonymy).



The elongate test tapers at the initial end. The early chambers are biserial but later chambers become irregularly uniserial and are wedge-shaped. The distinct, depressed sutures are oblique. The arched apertural depression is on one side of the terminal chamber with an over-hanging lip. A longitudinal section parallel to the apertural face reveals a funnel-like structure tapering down from the aperture to the preceding chamber. The test is finely perforate and smooth walled.

The dimensions of the figured specimen are: length = 0.64 mm, maximum width = 0.15 mm.

**DISCUSSION:** Only one complete specimen has been isolated and the apertural features are not clear; a tooth plate cannot be observed. The funnel-shaped internal tube and the chamber arrangement suggests either *Pleurostomella* Reuss, or *Ellipsoidella* Heron-Allen & Earland 1910 (refer Belford 1960, p. 72-73). The apertural depression is much wider than would be expected in *Ellipsoidella*, thus the specimens can be placed within the genus *Pleurostomella*. The external features of test shape and chamber arrangement agree with those of *P. subnodosa* Reuss.

**OCCURRENCE:** Very rare; found in Zonule A in Port Campbell No. 2 Well and Flaxmans No. 1 Well. This species is well known from Senonian deposits.

**FIGURED SPECIMEN:** Pl. LXXXII, fig. 9—GSM 58735 from a core sample at 5,950 ft in Port Campbell No. 2.

The sectioned specimen (GSM 58735 from 5,950 ft in Flaxmans No. 1) has not been figured.

### Genus *Valvulineria* Cushman 1926

#### *Valvulineria lenticula* (Reuss)

(Pl. LXXXII, fig. 10)

- 1845 *Rotalina lenticula* Reuss. *Verstein böhm. Kreide* p. 35, Pl. 12, fig. 17.  
 1936 *Valvulineria lenticula* (Reuss) Brotzen, *Sver. Geol. Unders.* C.396: 151-3, Pl. 11, fig. 5; Fig. 54-5 (with synonymy).  
 1957 *Valvulineria lenticula* (Reuss) Hofker, *Beih. geol. Jb.* 27: 380-1, Fig. 425.  
 1960 *Valvulineria lenticula* (Reuss) Belford, *Bur. Min. Resour. Aust. Bull.* 57: 75, Pl. 20, fig. 3-10.

The smooth, finely perforate test is trochoid. The spiral surface is flat, umbilical surface convex, and the periphery rounded. The spiral surface is evolute with 2 whorls visible and there are 7-8 chambers in the outer whorl. On the spiral surface the sutures are strongly curved, distinct, and the final suture is depressed. On the umbilical surface the sutures are slightly curved, being limbate earlier but later becoming narrower and depressed. The umbilicus is covered by a flap protruding from the terminal chamber. This flap is produced narrowly above the aperture.

The narrow aperture extends from the umbilicus for  $\frac{2}{3}$  of the length of the basal suture of the final chamber on the umbilical surface. The terminal face is rounded. The dimensions of the Victorian specimens are: maximum diameter = 0.2 mm to 0.4 mm, maximum height = 0.1 mm to 0.15 mm.

Reference has been omitted to the variant American material discussed and described by Harris & McNulty (1956) as *V. lenticula* (Reuss) in order to demonstrate closer similarities with the described European and Western Australian specimens of *V. lenticula*.

**DISTRIBUTION:** Fairly rare in the Victorian sequence. Its sporadic occurrence is limited to Zonule A. This species has a widespread distribution in the Upper Cretaceous.

**FIGURED SPECIMEN:** Pl. LXXXII, fig. 10—GSM 58751 from a core at 4,757 ft in Port Campbell No. 1.

***Valvulineria erugata* Belford**

(Pl. LXXXII, fig. 12)

1960 *Valvulineria erugata* Belford, *Bur. Min. Resour. Aust. Bull.* 57: 76, Pl. 20, fig. 11-18.

The calcareous test is granular in structure yet finely perforate. The trochoid test has a rounded periphery and is plano-convex; the spiral side is flat, although it may exhibit a slight degree of concavity or convexity.  $2\frac{1}{2}$  whorls are visible on the spiral side with 8 chambers in the outer whorl. On the spiral side, the sutures are narrow, distinct and curved backwards, while the later sutures are slightly depressed. The strongly convex umbilical surface has curved slightly depressed sutures. The wide umbilicus is covered by a thin flap extending from the terminal chamber. The narrow aperture extends from the umbilicus along the basal suture of the terminal chamber, but does not reach the periphery.

The diameter of specimens ranges from 0.25 mm to 0.3 mm while the height ranges from 0.13 mm to 0.15 mm.

**DISCUSSION:** The spiral face is not perfectly flat in all the Victorian specimens but is obviously a variant feature with several specimens closely resembling the described type material. The Victorian material has only 8 chambers to the whorl compared with 9-10 chambers in the Western Australian specimens.

**DISTRIBUTION:** Rare, only recorded in Zonule A. Occurs in the Santonian and lower Campanian in Western Australia.

**FIGURED SPECIMEN:** Pl. LXXXII, fig. 12—GSM 58749 from a core at 4,652 ft in Belfast No. 4.

***Valvulineria undulata* Belford**

(Pl. LXXXII, fig. 11)

1960 *Valvulineria undulata* Belford, *Bur. Min. Resour. Aust. Bull.* 57: 67-8, Pl. 20, fig. 19-24.

The trochoid test is unequally biconvex, the umbilical surface being more convex. The periphery is rounded. The evolute spiral surface has  $2\frac{1}{2}$  whorls with 8 chambers in the outer whorl. The narrow, distinct, smooth sutures are flexed backwards towards the outer margin and they are sinuous in the later chambers. The umbilical surface is involute with narrow radial sutures. The umbilicus is covered by a distinct plate. The apertural face is rhombic in outline. The calcareous test walls are granular and finely perforate.

The maximum diameter of specimens is 0.25 mm and the maximum height is 0.1 mm.

**DISCUSSION:** The illustrated specimen shows a greater trochospiral tendency than that illustrated for the type material. Apart from this and smaller size the Victorian material corresponds to *V. undulata*.

**DISTRIBUTION:** Found only in a core sample from 4,652 ft in Belfast No. 4 Bore, where it is associated with *V. erugata* Belford. Figured specimen, GSM 58750. The species occurs in the Santonian of Western Australia.

Genus *Gyroidinoides* Brotzen 1942*Gyroidinoides nitida* (Reuss)

(Pl. LXXXIII, fig. 1)

1845 *Rotalina nitida* Reuss, *Verstein bohm. Kreide* 1: 35, Pl. 7, fig. 8 & 20; Pl. 8, fig. 52.1942 *Gyroidinoides nitida* (Reuss) Brotzen, *Sver. Geol. Unders. C.* 396: 19, Fig. 6, 3.1946 *Gyroidina nitida* (Reuss) Cushman, *Prof. Pap. U.S. Geol. Surv.* 206: 140, Pl. 58, fig. 5.1957 *Gyroidinoides nitida* (Reuss) Hofker, *Beil. geol. Jb.* 27: 393-4, Fig. 437-440.

The perforate, smooth, shiny calcareous test is trocho-spirally coiled, circular in outline, though appears conical in side view. The spiral surface is flat, but this surface on the last chamber may be below the surface of the earlier chambers. On the spiral surface there are 3 whorls visible with 7 chambers in the outer whorl. The chambers increase gradually in size. The faintly curved, radial sutures are depressed. The periphery is rounded. The umbilical surface is involute, with a small umbilicus which may be partially covered by apertural lip and relic lips. The aperture is a narrow slit which reaches from the umbilicus towards the spiral surface. The aperture does not reach the spiral surface and its termination is marked by a distinct bulge in the terminal face. Below this bulge the terminal face is flat with a lip overhanging the umbilicus. The diameter of specimens ranges from 0.3 mm to 0.35 mm; the height from 0.2 mm to 0.24 mm.

**DISTRIBUTION:** Common to abundant in Assemblages 2 & 4 of Port Campbell No. 2 section, though it occurs rarely and sporadically in the rest of the sequence. A well-known species ranging from the Turonian to the Danian.

**FIGURED SPECIMEN:** Pl. LXXXIII, fig. 1—GSM 58707 from a core at 5,025 ft in Port Campbell No. 2.

*Gyroidinoides cruachin* sp. nov.

(Pl. LXXXIII, fig. 2)

**DESCRIPTION OF HOLOTYPE:** Pl. LXXXIII, fig. 2. GSM 58708.

The finely perforate smooth test is somewhat compressed as the diameter is twice the height. The dorsal surface is only slightly convex, as the chamber surfaces are flat but the spiralling is not horizontal and the later chambers are on a lower plane than the earlier ones. 3 whorls are visible dorsally with 12 chambers in the outer whorl. The sutures on both surfaces are radial, straight to slightly curved, and the last 2 sutures are depressed. The periphery is rounded. The convex ventral surface is involute with a wide open umbilicus which is filled by a clear calcite plug. The terminal chamber protrudes a little over the umbilicus and along the base of this chamber there is a very narrow convex flap. The slit-like aperture extends from the umbilicus almost to the periphery.

The diameter of the test is 0.3 mm, while the height is 0.15 mm. The Holotype is from a core sample at 4,710 ft in Port Campbell No. 1 Well.

**OBSERVATIONS OF OTHER SPECIMENS:** All resemble the holotype. The diameter ranges from 0.2 mm to 0.3 mm while the height from 0.1 mm to 0.15 mm.

**DISCUSSION:** This form is not as compressed as *G. depressa* (Alth) and also appears to differ in umbilical detail. The test of this form is less conical, has more chambers, and the umbilical flap is less developed than *G. nitida* (Reuss) with which it is often associated in the Victorian sequence. However, this species is very similar to the Upper Cretaceous form *G. pontoni* Brotzen, as described by Hofker (1957, p. 399-400), but *G. pontoni* has curved septae which are strongly flexed towards the inner margin of the whorl.



The specific name of *G. cruachin* is from the Gaelic; Crauchin being the place of origin and the rallying cry of the Clan Campbell. Thus, the specific name records its occurrence in the Cretaceous sequence of the Port Campbell wells.

OCCURRENCE: Fairly rare. Never recorded in cores below Zonule A.

### Genus *Alabamina* Toulmin 1941

#### *Alabamina australis* Belford

(Pl. LXXXIII, fig. 3-4; Pl. LXXXVI, fig. 6)

1960 *Alabamina australis australis* Belford, *Bur. Min. Resour. Aust. Bull.* 57: 84-86, Pl. 23, fig. 13-20; Fig. 4, 5.

1960 *Alabamina australis obscura* Belford, *ibid.*, p. 86, Pl. 24, fig. 1-8; Fig. 5.

The finely perforate smooth test is trochoid and plano-convex with a rounded periphery. The flat spiral side is evolute with 2-3 whorls visible and 5-6 chambers in the last whorl. The distinct sutures on the spiral surface are straight to faintly curved and are reflexed; the later sutures are slightly depressed. The convex umbilical surface is completely involute, and the sutures are radial, straight and convergic. The narrow aperture is at the base of the terminal chamber, extending from the umbilicus to the periphery, with a distinct groove into the final face just below and parallel to the periphery. In horizontal section, a tooth plate is visible in each chamber.

The diameter of specimens ranges from 0.15 mm to 0.3 mm and the ratio of diameter to height is 3:2 in all specimens.

Several specimens have been isolated in which the spiral surface is partially involute.

DISCUSSION: The spirally evolute forms are identical with the type description of *A. australis australis*, except that the Victorian specimens are of smaller size and the spiral sutures are not so strongly curved, though this factor may relate to size.

The few specimens that are partially involute on the spiral side could be assigned to *A. australis obscura*. But the two forms appear to intergrade in the Victorian material.

DISTRIBUTION: Apart from at the base of the sequence (Assemblage 5 in Port Campbell No. 2) this species occurs in both Zonules. The species is described from the Santonian of Western Australia, but its range could extend down to the Turonian.

FIGURED SPECIMENS: Pl. LXXXIII, fig. 3—GSM 58670 from a core sample at 4,757 ft in Port Campbell No. 1; fig. 4—GSM 58671 from a rotary cutting sample at 5,200-10 ft in Flaxmans No. 1 (partially involute specimen); Pl. LXXXVI, fig. 6—GSM 58790 from a core at 5,950 ft in Flaxmans No. 1.

### Genus *Cibicides* Montfort 1808

#### *Cibicides excavatus* Brotzen 1936

(Pl. LXXXIII, fig. 5-6; Pl. LXXXVI, fig. 4-5)

1936 *Cibicides excavatus* Brotzen, *Sver. geol. Unders. C.* 396: 189, Pl. 13, fig. 7, 8 (with synonymy).

1957 *Cibicides excavatus* Brotzen, Hofker, *Beih. geol. Jb.* 27: 84-94, Fig. 96.

1960 *Cibicides excavatus* Brotzen, Belford, *Bur. Min. Resour. Aust. Bull.* 57: 111, Pl. 34, fig. 12-16.

1962 *Cibicides excavatus* Brotzen, Ebensberger, *Palaeontographica* 120 (A): 96, Pl. 9, fig. 10.

The closely coiled planispiral tests are formed of coarse to medium grained calcium carbonate and are perforate on both sides. The 6 to 7 chambers in the outer whorl become increasingly inflated. This is apparent on the spiral dorsal

surface where the earlier chambers are flat faced, while the later ones form a convex face. The degree of chamber inflation may be interpreted as a growth factor, as the smallest specimens have flat dorsal surfaces. The dorsal surface is wholly or partially involute, while the convex umbilical (ventral) surface is completely involute. The periphery is round, though the margin is angular where there is dorsal flattening. The half-moon shaped aperture is along the marginal suture and is sometimes covered by a lip. The septae and test walls appear to be monolamellid.

**DIMENSIONS:** The smallest specimen has a diameter of 0.22 mm with a last chamber 0.11 mm high. The largest specimen has a diameter of 0.6 mm with a last chamber 0.45 mm high. These dimensional extremes illustrate the relationship between size and chamber inflation.

**DISTRIBUTION:** This species is restricted to Zonule A. It has been reported from the Santonian and lower Campanian of Europe and Western Australia, though Brotzen shows it to range into the Turonian, while Ebensberger records it from the Maastrichtian of Germany.

**FIGURED SPECIMENS:** Pl. LXXXIII, fig. 5—GSM 58685 from a core at 5,025 ft in Port Campbell No. 1; fig. 6—GSM 58684 from a core at 5,910 ft in Port Campbell No. 2. Pl. LXXXVI, fig. 4—GSM 58791 from a core at 5,910 ft in Port Campbell No. 2; fig. 5—GSM 58870 from a core at 5,950 ft in Flaxmans No. 1.

### ***Cibicides ribbingi* Brotzen**

(Pl. LXXXIII, fig. 7)

1936 *Cibicides ribbingi* Brotzen, *Sver. Geol. Unders. C.* 396: 186, Pl. 13, fig. 5, 6; Fig. 67, 68.  
1960 *Cibicides ribbingi* Brotzen, Belford, *Bur. Min. Resour. Aust. Bull.* 57: 111-2, Pl. 34, fig. 17-20.

The test is sub-round in outline and plano-convex in side view. The margin is acute with a narrow thickened keel in the earlier chambers. The flat to slightly concave spiral surface is partially evolute with 9 chambers in the outer whorl. The convex umbilical surface is completely involute and the umbilicus is covered. The low apertural arch extends from the periphery along the inner margin of the last few chambers on the spiral surface.

The granular calcareous test is perforate, although the granular structure is not as coarse grained as *C. excavata* of the Victorian sequence.

The figured specimen has a maximum diameter of 0.6 mm and a maximum height of 0.25 mm.

**DISTRIBUTION:** Occurs only in a core sample from 4,652 ft in Belfast No. 4, and rotary cutting sample from 4,695 ft in Port Campbell No. 1. Occurs in the Santonian of Europe and Western Australia.

**FIGURED SPECIMEN:** Pl. LXXXIII, fig. 7—GSM 58682 from a core sample at 4,652 ft in Belfast No. 4.

### **Genus *Hanzawaia* Asano 1944**

#### ***Hanzawaia californica* (Bandy)**

(Pl. LXXXIII, fig. 8; Pl. LXXXVI, fig. 7)

1951 *Cibicidina californica* Bandy, *J. Paleont.* 25: 505-6, Pl. 74, fig. 7.

The small, delicate test is circular in outline and plano-convex in side view. The flat to slightly concave dorsal surface is partially evolute. The convex ventral side is usually involute although one specimen exhibits slight evolution of the ventral

surface. There is a central umbo on both sides. There are 9-11 chambers in the final whorl, with only  $1\frac{1}{2}$  whorls in the test. The sutures are distinct, thickened and curved backwards, with dorsal re-entrants at the inner margin of the outer whorl. The low arched aperture extends from the periphery along the inner margin of the last 2 chambers on the dorsal surface (spiral surface). In some specimens the aperture is covered by a narrow lip. The calcareous test is hyaline with perforate walls. The umbilical plug is composed of cloudy imperforate calcite. The septal walls are monolamellid, although the chamber walls appear to be lined with dark substance (refer Pl. LXXXVI, fig. 7). The diameter of most specimens is 0.2 mm with a height of 0.1 mm.

**DISCUSSION:** The Victorian specimens compare closely with *H. californica* Bandy, although the holotype is twice their size.

**DISTRIBUTION:** Fairly rare. Occurs only in Zonule A. The species is reported only from the Campanian of California.

**FIGURED SPECIMENS:** Pl. LXXXIII, fig. 8—GSM 58686 from a core at 5,025 ft in Port Campbell No. 1. Pl. LXXXVI, fig. 7—GSM 58792 from a core at 4,974 ft in Port Campbell No. 1.

### Genus *Gavelinopsis* Hofker 1951

#### *Gavelinopsis cenomanica* (Brotzen)

(Pl. LXXXIII, fig. 9; Pl. LXXXVI, fig. 8-9)

1945 *Cibicidoides* (*Cibicides*) *cenomanica* Brotzen, *Sver. Geol. Unders. C.* 465, Pl. 2, fig. 2.

1957 *Gavelinopsis cenomanica* (Brotzen) Hofker, *Beih. geol. Jb.* 28: 321-2, Fig. 370.

The bi-convex test has an acute margin with a keel in the earlier chambers, but the margin is rounded and without a keel in the later chambers. 2 whorls visible on dorsal surface, although some of the chambers in the first whorl are partially obscured by the secondary calcite which covers the inner whorl. 9-10 chambers are visible in the outer whorl with the earlier chambers flattened dorsally while the later chambers are more inflated. The sutures curve backwards on both surfaces, dorsally they are limbate in the earlier portion but become narrower and depressed, ventrally the sutures are depressed but are infilled with clear secondary calcite to the extent of appearing raised. The ventral surface is almost completely involute with all chambers convex. The umbilicus is deep, although it is infilled with secondary calcite. The narrow apertural lip can be seen to extend halfway round the inner margin of the whorl, overhanging the umbilical surface. The apertural face extends farther on the ventral surface than on the dorsal. The apertural slit is basal and is only ventral.

The bi-lamellid test walls and septa are finely perforate. The secondary calcite veneer is imperforate and its extent is illustrated by the areas lacking pores on the figures. As is illustrated and already described, the secondary calcite is not confined to the umbilical hollow on both surfaces. The term umbilical boss or plug is not used, for veneer is regarded as more applicable.

Maximum diameter of specimens varies from 0.45 mm to 0.65 mm while the height from 0.18 mm to 0.24 mm.

**DISCUSSION:** The Victorian material compares closely with that described by Hofker (1957) from the Cenomanian of Holland and NW. Germany. In the original description, Brotzen (1945) states that the sutures are raised, but Hofker (loc. cit.) indicates that the sutures may not appear raised, due to secondary calcite infilling; this is verified in the Victorian material.

Belford (1960, p. 101-3) and other authors doubt the generic validity of



*Gavelinopsis*. Hofker's generic determination of *G. cenomanica* has been accepted by the author and Hofker's designation of dorsal and ventral surfaces has been followed in order to achieve descriptive uniformity. The Victorian material, though determinant, is too poorly preserved for close generic study.

**DISTRIBUTION:** This species is confined to Zonule B of which it is characteristic, although it does not extend to the lower horizons of the Zonule as does *Textularia trilobita*. *G. cenomanica* is often associated with a smaller form of *Gavelinopsis* so poorly preserved as to be indeterminate. Was originally reported from the upper Albian and Cenomanian, Hofker has extended its range to the Turonian.

**FIGURED SPECIMENS:** Pl. LXXXIII, fig. 9—GSM 58702 from a core at 7,000 ft from Port Campbell No. 2. Pl. LXXXVI, fig. 8—GSM 58797 from a core at 7,000 ft from Port Campbell No. 2; fig. 9—GSM 58796 from a cutting sample at 7,650-7,660 ft in Port Campbell No. 2.

### *Gavelinopsis* cf. *eriksdalensis* (Brotzen)

(Pl. LXXXIII, fig. 10)

1936 *Cibicides* (*Cibicidoides*) *eriksdalensis* Brotzen, *Sver. Geol. Unders.* 396: 193, Pl. 14, fig. 5; Fig. 69.

1957 *Gavelinopsis eriksdalensis* (Brotzen) Hofker, *Beih. geol. Jb.* 27: 322-4; Fig. 371, 372.

1960 *Anomalinoides eriksdalensis* (Brotzen) Belford, *Bur. Min. Resour. Aust. Bull.* 57: 108-9, Pl. 34, fig. 1-11.

The bi-convex test has an acute margin with a narrow thickened keel in the earlier chambers. The ventral surface is partially evolute with 2 whorls visible and with 8-10 chambers in the outer whorl. The dorsal surface is involute with a prominent umbilical plug. The sutures are indistinct, narrow, and curve slightly backwards. The narrow aperture extends ventrally from the periphery to halfway along the inner margin of the outer whorl. The test is composed of coarsely perforate, granular calcite. The calcite of the umbilical plug is particularly coarse grained and is opaque. The septal walls are bi-lamellid.

The maximum diameter of specimens ranges from 0.33 mm to 0.4 mm, and the thickness from 0.15 mm to 0.2 mm.

**DISCUSSION:** This Victorian form differs from *G. eriksdalensis* in that the umbilical plug is larger and the ventral surface is more involute. Brotzen (1945) notes an increase in size of the umbilical plug, but this increase in size is accompanied by a surface flattening of the plug, which is not a feature of the Victorian form.

**DISTRIBUTION:** Rare, but occurs throughout the sequence. This species is present in the Santonian and Campanian of Europe.

**FIGURED SPECIMEN:** Pl. LXXXIII, fig. 10—GSM 58705 from a cutting sample at 5,650 to 5,660 ft in Flaxmans No. 1.

A vertical section of specimen GSM 58799 has not been figured.

### Genus *Ceratobulimina* Toulou 1920

#### *Ceratobulimina kremnoides* sp. nov.

(Pl. LXXXIV, fig. 1-2)

**DESCRIPTION OF HOLOTYPE:** GSM 58680. Pl. LXXXIV, fig. 1.

The smooth, perforate, calcareous test is flatly coiled and its length is greater than its width (ratio = 4:3). The periphery is rounded, while both faces are some-

what flattened. 2½ whorls are visible on the spiral side with 6 chambers in the outer whorl. The sutures are distinct, being limbate, especially on the spiral side, and depressed on the umbilical side. The involute umbilical face slopes into the deltaic shaped umbilicus. The apex of this 'delta' is the apertural slit which extends into the umbilical face of the terminal chamber. There are also indentations into the test where the sutures meet the umbilicus. In edge view, the terminal face is abrupt, being steep though slightly curved.

The test is 0.45 mm long, 0.32 mm wide, and 0.2 mm thick.

The specimen is from a rotary cutting sample at 6,500-10 ft in Flaxmans No. 1 Well.

DESCRIPTION OF SUPPLEMENTARY SPECIMEN: GSM 58681. Pl. LXXXIV, fig. 2.

The test is more circular and convex in outline and the terminal face is more abrupt in edge view than in the Holotype. There are 7 chambers in the outer whorl. The terminal chamber is infilled with pyritic mud, which is a common feature in other specimens of this species.

The test is 0.45 mm long, 0.38 mm wide, and 0.25 mm thick.

The specimen is from a core sample at 5,910 ft in Port Campbell No. 2 Well.

The length of unfigured specimens ranges from 0.2 mm to 0.45 mm.

DISCUSSION: The abrupt terminal face and the delta shape of the umbilicus are the major features that differentiate this species from other Cretaceous *Ceratobulimina*. Apart from these characters, the Albian species, *C. gaultina* ten Dam 1947 and *C. woodi* Khan 1950, are flatter and more elongate, while the Upper Cretaceous *C. cretacea* Cushman & Harris 1927 is more elongate and the sutures more distinctly limbate.

However, *C. kremnoides* compares closely with the Paleocene species *C. westraliensis* Parr 1938, but the examination of topotype and other material of this species (including specimens from the Paleocene at Pebble Point, Victoria) has shown that, in *C. westraliensis*, the terminal face is gently sloping and the umbilicus tends to be elongate rather than deltaic. The specific name of *C. kremnoides* refers to the abrupt terminal face of the test (Kremnos (Gk), cliff or precipice).

DISTRIBUTION: This species is very rare in the sequence.

### ***Ceratobulimina cretacea* Cushman & Harris**

(Pl. LXXXIV, fig. 3)

- 1927 *Ceratobulimina cretacea* Cushman & Harris, *Contr. Cushman Lab.* 3: 173, Pl. 29, fig. 1; Pl. 30, fig. 11.
- 1946 *Ceratobulimina cretacea* Cushman & Harris, Cushman, *Prof. Pap. U.S. Geol. Surv.* 206: 143, Pl. 59, fig. 6-7 (with synonymy).
- 1951 *Ceratobulimina cretacea* Cushman & Harris, Bandy, *J. Paleont.* 25 (4): 507, Pl. 73, fig. 20.
- 1954 *Ceratobulimina cretacea* Cushman & Harris, Frizzell, *Rep. Inv. Univ. Texas econ. Geol.* 22: 125, Pl. 19, fig. 13.

The smooth walled, finely perforate test is ovoid, bi-convex in side view, and the periphery is rounded. The spiral, dorsal surface is evolute with 2 whorls, and with 6 chambers in the outer whorl; the chambers increase rapidly in size. The sutures are slightly limbate on both surfaces, dorsally they are curved, ventrally nearly straight and radial. The evolute ventral surface has a well developed umbilicus. The aperture is a narrow cleft in the terminal face and leads into the umbilicus. The only complete specimen has a length of 0.3 mm, a width of 0.2 mm, and a thickness of 0.15 mm.

DISCUSSION: The differences between this species and *C. kremnoides* sp. nov. are obvious on comparing the specimens. The former is more elongate and all sutures more distinct. The aperture is visible in edge view in *C. cretacea*, while it is only visible on the umbilical face of *C. kremnoides*.

DISTRIBUTION: Isolated only in a core sample from 4,757 ft in Port Campbell No. 1 Well. GSM 58682. Commonly reported in the Campanian of North America.

### Genus *Hedbergella* Bronnimann & Brown 1958

Considerable revision of the Cretaceous globigerinids has taken place during the last 7 years. This has especially affected the non-keeled forms in which the apertures are interiomarginal extraumbilical-umbilical arches, and have open umbilici. Bronnimann & Brown (1956) proposed the genus *Hedbergina* to include such forms, but the proposed genotype *Globigerina seminolensis* Harlton 1927, was shown not to be acceptable. Bolli, Loeblich and Tappan (1957) included such forms within the genus *Praeglobotruncana* Bermudez 1952, together with keeled forms with similar apertural and umbilical features as shown in the genotype *Globorotalia delrioensis* Plummer 1931. The genus *Hedbergella* was then established by Bronnimann & Brown (1958) with *Anomalina lorneiana* d'Orbigny var. *trocoidea* Gandolfi 1942, as the Genotype. Banner & Blow (1959) gave *Hedbergella* subgeneric status within the genus *Praeglobotruncana*. In a study of globigerinids in the 'Complexe schisteux intermédiaire', Klaus (1959) was satisfied with the status of *Hedbergella*. He described only the genotypic species *H. trocoidea* (Gandolfi) from the Albian to Turonian stages, although he mentions stratigraphic variation in size, chamber arrangement, and height of spire. In a recent study, Loeblich & Tappan (1961) have separated *Hedbergella* from *Praeglobotruncana*, mainly on the presence or absence of a peripheral keel. They have described 8 species of *Hedbergella* (5 of the species are generically redefined) which are designated on size, shape, chamber arrangement, number of chambers, and height of spire. From the descriptions and figures it is difficult to distinguish between some of the species so, with reference to the work of Klaus (loc. cit), one cannot dismiss the possibility that some of Loeblich & Tappan's species are conspecific variants due to vertical distribution, environment or even population differences.

Hofker (1961) refuses to recognize current taxonomic findings, as he places the non-keeled members of *Praeglobotruncana* (= *Hedbergella*) within his *Globigerina cretacea* 'gens' and illustrates traceable variation in size, chamber arrangement and number, height of spire and ornamentation. But Hofker includes in his 'gens' forms which do not have interiomarginal, extraumbilical-umbilical arched apertures, and he also includes a form with an umbilical covering plate. Hofker believes that these two features are artificial generic characters, yet they are features which are clearly either present or absent. They can hardly be described as variable features. Therefore, I am of the opinion that Hofker's 'gens' includes 3 genera, namely *Globigerina*, *Hedbergella*, and *Rugoglobigerina*. Hofker's study on NW. European material clearly shows that there is a traceable stratigraphic variation of specimens which can be included in the genus *Hedbergella*, namely his Pl. 1, fig. 5-14.

Upon this review of the literature the generic status of *Hedbergella* is accepted for the purpose of this study. It has clearly distinguishable features from the following superficially similar genera:

- (1) *Globigerina* d'Orbigny 1826—which has an arched umbilical aperture which does not extend to the margin.



- (2) *Praeglobotruncana* Bermudez 1952—which has a peripheral keel which is often better developed in the early stages.
- (3) *Ticinella* Reichel 1950 and *Rugoglobigerina* Bronnimann 1952—which have secondary apertures on the umbilical side. The latter genus has an umbilical cover plate.

Loeblich and Tappan (1961) have elevated *Clavihedbergella* to generic rank after Banner & Blow (1959) had designated it as a sub-genus of *Praeglobotruncana*. Its radially elongate chambers distinguish it from *Hedbergella*. Loeblich & Tappan's figures on Pl. 3 seem to show that chamber elongation is not a clear-cut generic feature, as *H. amabilis* Loeblich & Tappan blend with *C. simplex* (Morrow) (fig. 5 & 14 appear to be the two extremes). Thus, the generic status of *Clavihedbergella* is dubious.

### ***Hedbergella trocoidea* (Gandolfi)**

(Pl. LXXXIV, fig. 4-7)

- 1942 *Anomalina lorneiana* var. *trocoidea* Gandolfi, *Riv. Ital. Pal.* 48 (4): 99, Pl. 2, fig. 1; Pl. 4, fig. 2, 3; Pl. 13, fig. 2-5.
- 1942 *Anomalina lorneiana* Gandolfi (non d'Orbigny), *Riv. Ital. Pal.* 48 (4): 98, Pl. 4, fig. 1, 19; Pl. 8, fig. 2; Pl. 13, fig. 1, 4.
- 1956 *Hedbergina seminolensis* Bronnimann & Brown (non Harlton), *Eclog. Geol. Helv.* 48 (2): 529, Pl. 20, fig. 4-6.
- 1958 *Hedbergella trocoidea* (Gandolfi), Bronnimann & Brown, *Washington Acad. Sci.* 48 (1): 16, Fig. 1.
- 1959 *Praeglobotruncana* (*Hedbergella*) *trocoidea* (Gandolfi), Banner & Blow, *Palaeontology* 2 (1): p. 18 (no figure).
- 1959 *Hedbergella trocoidea* (Gandolfi), Klaus, *Eclog. Geol. Helv.* 52 (2): 792, Pl. 1, fig. 1.
- 1961 *Globigerina cretacea* d'Orbigny, Hofker (in part), *Micropaleontology* 7 (1): 96-98, Pl. 1, fig. 5-15 only.
- 1961 *Hedbergella trocoidea* (Gandolfi), Loeblich & Tappan, *Micropaleontology* 7 (3): 277-8, Pl. 5, fig. 1-2.
- 1961 *Hedbergella amabilis* Loeblich & Tappan, *Micropaleontology* 7 (3): 274, Pl. 3, fig. 2, 3, 5, 7.

The small, perforate, trochoidal test is flat to slightly convex on the spiral side and convex on the umbilical side. It is sub-round to sub-angular in peripheral outline. The chambers are ovoid to globular in shape, increasing rapidly in size as added; 5 to 6 chambers to the whorl with 2 to 3 whorls visible on the spiral side. Some of the chambers are radially elongate, but this is not a persistent feature in any one specimen. The radial sutures are straight, distinct, and depressed on both sides. The margin lacks a keel and is indented at the sutures. The degree of indentation depends on the degree of radial elongation of the chambers. Only the last whorl is visible on the umbilical side, where the umbilicus is narrow, deep, and open, though sometimes fringed with relic apertural lips. The aperture is an interiomarginal, extraumbilical to umbilical arch partially covered by a lip which flares out over the umbilicus.

The maximum diameter ranges up to 0.28 mm; the terminal chamber is as high as 0.15 mm, with a height of 0.05 mm for the first chamber in the last whorl.

**DISCUSSION:** The Victorian specimens show variation in chamber shape but morphologically intergrade within the one sample. As already mentioned, both Klaus (1959) and Hofker (1961) show variation in form within a species assignable to *H. trocoidea*. Some of the Victorian specimens could be assignable to *H. amabilis* Loeblich & Tappan 1961 if they were specifically finite from the other specimens in the sample. Morphological intergradations have been observed in living populations of globigerinids, as discussed by Bé (1959, p. 84). The Victorian specimens of *H. trocoidea* are smaller than those described by other authors. The study of recent

globigerinids has shown that size variation within a species may be influenced by the environment, especially temperature, as is suggested by Bradshaw (1959, p. 57-59). (The Victorian fauna is believed to be a cold water fauna.)

**PRESERVATION:** Most of the Victorian specimens were partially covered by matrix. The only satisfactory method of cleaning was found to be in the alteration of calcium carbonate test material to calcium fluoride by the method described by Sohn (1956). This eliminated any siliceous material adhering to the test, but the only specimens successfully treated were those free from cracks or pyrite. The treatment cleans out the pores in the test walls, so treated specimens appear to be different in texture from untreated ones.

**DISTRIBUTION:** This species has not been found in any core sample below Zonule A, where it is usually rare, though common in some samples. The presence of several specimens at 5,540-49 ft in Zonule A in Port Campbell No. 1 is unreliable as the sample is from rotary cuttings.

The restricted range of *H. trocoidea* in the Victorian sequence is regarded as an environmental factor rather than a stratigraphic one. The species is reported from Albian to Turonian, but the generic range may be higher.

**FIGURED SPECIMENS:** Pl. LXXXIV, fig. 4—GSM 58709 (fluoride replacement) from a core at 5,025 ft in Port Campbell No. 1; fig. 5—GSM 58711 from a core at 4,757 ft in Port Campbell No. 1; fig. 6—GSM 58712 (calcite mould) from a cutting sample at 5,540 ft to 5,549 ft in Port Campbell No. 1; fig. 7—GSM 58710 (fluoride replacement) from a core at 5,025 ft in Port Campbell No. 1.

#### Genus *Guembelina* Egger 1899

##### *Guembelina reussi* Cushman

(Pl. LXXXIV, fig. 8)

- 1938 *Gümbelina reussi* Cushman, *Contr. Cushman Lab.* 14: 11, Pl. 2, fig. 6-9.  
 1946 *Gümbelina reussi* Cushman, *Prof. Pap. U.S. Geol. Surv.* 206: 104, Pl. 44, fig. 18, 19 (with synonymy).  
 1954 *Gümbelina reussi* Cushman, Frizzell, *Rep. Inv. Univ. Texas econ. Geol.* 22: 110, Pl. 15, fig. 38.

The smooth, finely perforate, bi-serial test is  $1\frac{1}{2}$  times as long as wide. The periphery is straight in the earlier portion but later it is indented at the sutures. There are 6-8 pairs of chambers which are globular. The sutures are distinct, depressed, and angled slightly ( $10^\circ$ ) back. There is an indented triangular area between any 3 of the later chambers. The aperture is high and semicircular in the terminal face reaching down to the marginal suture. The test wall is thickened round the aperture and projects as a lip in some specimens. The length of specimens ranges from 0.2 mm to 0.45 mm, width from 0.15 mm to 0.28 mm, thickness from 0.1 mm to 0.2 mm.

**DISCUSSION:** The Victorian specimens are characterized by the high semicircular aperture and the indented area between the chambers which do not appear to overlap. These are features which differentiate this species from the more widespread *G. globulosa* (Ehrenberg).

**DISTRIBUTION:** Always associated with *Hedbergella trocoidea*. Reported from the Senonian of North America.

**FIGURED SPECIMEN:** Pl. LXXXIV, fig. 8—GSM 58706 from a core at 5,910 ft in Port Campbell No. 2.

Genus *Hoeglundina* Brotzen 1948*Hoeglundina subcretacea* (ten Dam)

(Pl. LXXXIV, fig. 9)

- 1925 *Epistomina caracolla* Franke (not Roemer), *Geol. Pal. Inst. Univ. Greifswald Abh.* t. 6: 88, Pl. 8, fig. 10.  
 1946 *Epistomina caracolla* Franke (not Roemer), Cushman, *Prof. Pap. U.S. Geol. Surv.* 206: 142-3, Pl. 59, fig. 2.  
 1948 *Epistomina supracretacea* ten Dam, *Revue de L'Institut Francais et Annales des Combustibles Liquides* 111 (6): 163, Pl. 1, fig. 8.  
 1951 *Höglundina supracretacea* (ten Dam), Bandy, *J. Paleont.* 25 (4): 507-8, Pl. 74, fig. 3 (with synonymy).  
 1960 *Höglundina supracretacea* (ten Dam), Takayanagi, *Sci. Reps. Tohoku Univ.* 2nd series (Geology), 32 (1): 127-8, Pl. 9, fig. 2.

The calcareous test is almost circular, and is unequally bi-convex. The margin is acute with a slight keel. The less convex dorsal side is evolute with 2-3 whorls visible and with 7-8 chambers in the outer whorl. The sutures are limbate, dorsally they are flexed backwards and are faintly curved, ventrally they are straight radiating out from the central umbo. The aperture is indistinct but appears to be a narrow slit along the basal suture of the terminal chamber on the ventral side. Diameter of specimens ranges from 0.3 mm to 0.51 mm, thickness from 0.15 mm to 0.32 mm.

DISCUSSION: Although all the Victorian specimens are poorly preserved (some replaced by pyrite), they appear to be fairly typical of this species.

DISTRIBUTION: Occurs rarely and sporadically in the sequence. Reported from the Senonian.

FIGURED SPECIMEN: Pl. LXXXIV, fig. 9—GSM 58704 from a cutting sample at 6,200 to 6,210 ft in Flaxmans No. 1.

Genus *Colomia* Cushman & Bermudez 1948*Colomia austrotrochus* sp. nov.

(Pl. LXXXII, fig. 1-4; Pl. LXXXVI, fig. 1-3)

DIAGNOSIS: The test is circular in transverse section; conical in the early portion with an initial apiculate end; conical, cylindrical, or bulbous later. The calcareous test is bi-lamellid and finely perforate. The exterior walls are hispid to varying degrees. The initial chambers are trochospirally coiled with a proloculus. The later 3 chambers are uniserial, though the trochospiral tendency is still apparent. The narrow, distinct sutures are flush with the surface or slightly depressed. The sutures are oblique, the angle alternates so that the chambers are wedge-shaped, the obliqueness may decrease with chamber addition. The terminal aperture is an elongate narrow opening, slightly curved at both ends. There is a thin apertural lip on one side of the opening. Often in the terminal face, there is a hollow which contains the aperture. A thin section, cut perpendicular to the aperture, reveals 2 vertical columns extending from the aperture towards, but not reaching, the preceding septal wall. The distance between the columns is greater than the width of the aperture so that the apertural lip covers most of this opening. The apertural columns may be missing in every second chamber, which suggests that the position and orientation of the aperture must alternate.

Length of specimens ranges from 0.3 mm to 0.45 mm, maximum diameter from 0.22 mm to 0.3 mm.

DESCRIPTION OF HOLOTYPE: Pl. LXXXII, fig. 1. GSM 58691.



A conical specimen with a sloping terminal face. Apertural detail a little indistinct. The initial chamber arrangement is distinctly trochospiral.

Length = 0.38 mm, maximum diameter = 0.27 mm.

The specimen is from rotary cutting samples from 5,460-70 ft in Port Campbell No. 1.

DESCRIPTION OF SUPPLEMENTARY SPECIMEN A: Pl. LXXXII, fig. 2. GSM 58690.

The test is conical with a small apical angle. The exterior surface is distinctly hispid. The uniserial sutures are only slightly oblique. The terminal chamber has been removed so as to reveal clear apertural detail. There is a definite apertural lip on one side of the aperture.

Length = 0.44 mm, maximum diameter = 0.3 mm.

The specimen is from rotary cutting samples at 5,400-10 ft in Port Campbell No. 1.

DESCRIPTION OF SUPPLEMENTARY SPECIMEN B: Pl. LXXXII, fig. 3. GSM 58692.

The final portion of the test is cylindrical in shape with very oblique depressed sutures and a steep final face. The aperture is within an elongate hollow open at the margin where the chamber is thinnest. The exterior surface is finely hispid.

Length = 0.37 mm, maximum diameter = 0.2 mm.

The specimen is from a rotary cutting sample at 5,400-10 ft in Port Campbell No. 1.

DESCRIPTION OF SUPPLEMENTARY SPECIMEN C: Pl. LXXXII, fig. 4. GSM 58689.

The test is slightly bulbous with a conical initial end. The uniserial sutures are extremely oblique. The terminal chamber is small and 3-sided, as if the test was reverting to the initial bi-serial, trochospiral chamber arrangement. The typical aperture is in an elongate hollow which runs down the steep terminal face and meets the suture of the preceding chamber.

Length = 0.38 mm, maximum diameter = 0.23 mm.

Specimen from rotary cuttings at 5,460-70 ft in Port Campbell No. 1.

DESCRIPTION OF SUPPLEMENTARY SPECIMEN D: Pl. LXXXVI, fig. 1. GSM 58793.

The longitudinal section cut perpendicular to the direction of the aperture. Clearly shows the apertural columns and the covering lip of the aperture in the third last chamber.

Length = 0.4 mm, maximum diameter = 0.28 mm.

The specimen is from 5,400-10 ft in Port Campbell No. 1.

DESCRIPTION OF SUPPLEMENTARY SPECIMEN E: Pl. LXXXVI, fig. 2. GSM 58794.

Longitudinal section cut parallel to the direction of the aperture. Shows 2 chambers to the whorl in the initial portion and the proloculus.

Length = 0.36 mm, maximum diameter = 0.25 mm.

Specimen from rotary cutting sample at 5,400-10 ft in Port Campbell No. 1.

DESCRIPTION OF SUPPLEMENTARY SPECIMEN F: Pl. LXXXVI, fig. 3. GSM 58795.

Transverse section of initial end above the proloculus. The section has been left thick so as to illustrate the spiral nature of the chamber wall. The chamber wall

curves into the centre of the test where it joins a small ovoid area suggestive of an umbilicus.

Diameter = 0.13 mm.

Specimen from rotary cutting sample at 5,400-10 ft in Port Campbell No. 1.

DISCUSSION: The conical, hispid test with the linear, uniserial arrangement of the later chambers are external characters of the Genus *Colomia*. Moreover, section reveals internal apertural structures similar to those described in the genotype, *C. cretacea* Cushman & Bermudez 1948. In a thorough taxonomic study of the genotype, Hofker (1958) shows many features which are described here in *C. austrotrachus*. This evidence fully confirms the generic identity of the Victorian form.

The author concurs with Hofker (loc. cit) in that *Colomia* shows an apparent relationship with the Genus *Conorboides*, rather than being a member of the Buliminidae, as suggested by Cushman & Bermudez (1948). Furthermore, the author suggests that *C. austrotrachus* may be an intermediary form in the supposed lineage between *Conorboides* and the other 3 described species of *Colomia*. This opinion is based on the fact that the Victorian form is more noticeably trochospiral than the other members of the genus, the trochospiral tendency being still apparent in the uniserial chambers. In fact, in some specimens, the uniserial chambers almost revert to a trochospiral arrangement, as in Supplementary Specimen C (Pl. LXXXII, fig. 4.). It should also be noted that *C. austrotrachus* is the oldest species of the genus as yet recorded. *C. californica* Bandy is from the Campanian, while the genotype and *C. orthostoma* Klsz are recorded from the Maastrichtian. The Victorian species is restricted to Zonule B which the author places within the Turonian Stage.

The external shape of *C. austrotrachus* is a variant feature. The shape appears to depend on the degree of trochospirality in the test, which is expressed by the sutural angle of the terminal chambers. With a low sutural angle, the test is conical (e.g. Holotype and Supplementary Specimen A); with a high sutural angle it is cylindrical (Supplementary Specimen B); and with a more acute sutural angle it is bulbous (Supplementary Specimen C).

Hofker (loc. cit.) shows that *C. cretacea* is a dimorphic form. This could well be the explanation to the variation with the Victorian species, the conical form being megalospheric, and the more trochospiral, cylindrical to bulbous form being microspheric. With the available material, this assumption cannot be confirmed. Bandy (1951) differentiates his species, *C. californica*, into 2 varieties on whether they are conical or cylindrical. It is noteworthy that Bandy's figures suggest that the cylindrical form, *C. californica californica*, shows more trochospirality than the conical form, *C. californica mundula*.

The specific name of *C. austrotrachus* relates to its noticeable trochoid nature and its geographic occurrence.

DISTRIBUTION: A characteristic species of Zonule B, to which it is confined.

### Bibliography

References for foraminiferal taxonomy are given in the synonymy with the species concerned and are not included here.

BAAS BECKING, L. G. M., GAPLAN, I. R., and MOORE, D., 1960. Limits of natural environment in terms of pH and oxidation-reduction potentials. *J. Geol.* 68 (3): 243-284.

BAIN, J. S., and MCQUEEN, A. F. New formation names. Appendix to completion reports of Port Campbell No. 1 and No. 2 wells. *Commonwealth Petroleum Search Subsidy Acts Publication* (in press).

- BAKER, G., 1943. Eocene deposits south east of Princetown, Victoria. *Proc. Roy. Soc. Vict.* 55: 237-256.
- , 1950. The geology and physiology of the Moolight Head district, Victoria. *ibid.* 60: 17-43.
- , 1953. The relationships of the *Cyclammina*-bearing sediments to the older Tertiary deposits south east of Princetown, Victoria. *Mem. Nat. Mus. (Melbourne)* 18: 125-134.
- , 1961. Studies of Nelson Bore sediments, Western Victoria. *Geol. Surv. Vict. Bull.* 58.
- , 1963. Oil well samples from Mesozoic sediments in the region west of the Otway Ranges, south west Victoria. *CSIRO Mineragraphic Investigations Rcp.* 860.
- BAKER, G., and COOKSON, I. C., 1955. The age of the Nelson Bore sediments. *Aust. J. Sci.* 17 (4): 133-134.
- BANDY, O. L., 1951. Upper Cretaceous Foraminifera from the Carlsbad area, San Diego County, California. *J. Paleont.* 25 (4): 488-513.
- BANNER, F. T., and BLOW, W. H., 1959. The classification and stratigraphic distribution of the Globigerinaceae. *Palaeontology* 2 (1): 1-27.
- BARTENSTEIN, H., and BRAND, E., 1951. Mikropalaontologische Untersuchungen zur Stratigraphie des nordwestdeutschen Valendis. *Abh. Senck. Naturf. Ges.* 485: 239-336.
- BĚ, A. W. H., 1960. Ecology of recent planktonic Foraminifera: Part 2—Bathymetric and seasonal distributions in the Sargasso Sea off Bermuda. *Micropalaeontology* 6 (4): 373-392.
- BELFORD, D. J., 1958. The stratigraphy and micropalaeontology of the Upper Cretaceous of Western Australia. *Geol. Rdsch.* 47 (2): 629-647.
- , 1960. Upper Cretaceous Foraminifera from the Toolonga Calcilutite and Gingin Chalk, Western Australia. *Bur. Min. Resour. Aust. Bull.* 57.
- BOLLI, H. M., LOEBLICH, A. R., and TAPPAN, H., 1957. Planktonic foraminiferal families Hantkeninidae, Orbulinidae, Globorotalidae and Globotruncanidae. *Bull. U.S. Nat. Mus.* 215: 3-50.
- BOUTAKOFF, N. A., 1952. The structural pattern of south west Victoria. *Vict. Min. & Geol. J.* 4 (6): 21-29.
- BRADSHAW, J. A., 1959. Ecology of living planktonic Foraminifera of the North and Equatorial Pacific Ocean. *Contr. Cushman Fdn.* 10 (2): 25-64.
- BRONNIMANN, P., and BROWN, N. K., 1956. Taxonomy of the Globotruncanidae. *Ecol. Geol. Helv.* 48 (2): 503-561.
- , and ———, 1958. *Hcdbergella*, a new name for a Cretaceous foraminiferal genus. *Washington Acad. Sci. J.* 48 (1): 15-17.
- BROTZEN, F., 1936. Foraminiferen us dem Schwedischen untersten Senon von Eriksdal in Schonen. *Sver. Geol. Unders. Ser. C* (396).
- , 1945. De Geologiska resultatn fran Borringnara vid Höllviken. *Sver. Geol. Unders. Ser. C* (465).
- BURNABY, T. P., 1962. Palaeoecology of the Foraminifera of the Chalk Marl. *Palaeontology* 4 (4): 599-608.
- COOKSON, I. C., and BALME, B. E., 1962. *Amosopollis cruciformis* gen. et. sp. nov., a pollen tetrad from the Cretaceous of Western Australia. *J. Roy. Soc. West. Aust.* 45 (4): 97-99.
- COOKSON, I. C., and DETTMANN, M. E., 1958. Some trilete spores from upper Mesozoic deposits in the eastern Australian region. *Proc. Roy. Soc. Vict.* 70 (2): 95-128.
- COOKSON, I. C. and EISENACK, A., 1961. Upper Cretaceous microplankton from Belfast No. 4 Bore, south western Victoria. *ibid.* 74 (1): 69-76.
- CRESPIN, I., 1954. The Nelson Bore, south western Victoria, micro-palaeontology and stratigraphic succession. *Bur. Min. Resour. Aust. Rept.* 11.
- CUSHMAN, J. A., 1934. The generic position of '*Cornuspira cretacea* Reuss'. *Contr. Cushman Lab.* 10 (2): 44-47.
- , 1946. Upper Cretaceous Foraminifera of the Gulf Coast region of the United States and adjacent areas. *Prof. Pap. U.S. Geol. Surv.* 206: 1-241.
- , 1950. *Foraminifera; their Classification and Economic Use*—4th ed., Harvard Uni. Press, 605 p.
- CUSHMAN, J. A., and BERMUDEZ, P. J., 1948. *Colonia*, a new genus from the Upper Cretaceous of Cuba. *Contr. Cushman Lab.* 24 (1): 12-13.
- DOUGLAS, J. G., 1960. Microplankton of the Deflandreidae group in Western District sediments. *Vict. Mining & Geol. J.* 6 (4): 17-33.
- EDWARDS, A. B., 1962. Notes on the geology of the Lorne district, Victoria. *Proc. Roy. Soc. Vict.* 75 (1): 101-119.



- FENTON, C. L., and FENTON, M. A., 1928. Ecologie interpretation of some biostratigraphic terms. *Am. Midland Nat.* 11: 1-40.
- GLAESSNER, M. F., 1945. *Principles of Micropalaeontology*. Melbourne Uni. Press. 296 p.
- , 1955. Taxonomic, stratigraphic and ecologie studies of Foraminifera and their inter-relations. *Micropalaeontology* 1 (1): 3-8.
- , 1959. Tertiary stratigraphic correlation in the Indo-Pacific region and Australia. *J. Geol. Soc. India* 1: 53-69.
- , 1962. Isolation and Communication in the geological history of the Australian fauna. p. 242-249 in *The Evolution of Living Organisms*, ed. G. W. Leeper, Melbourne Uni. Press.
- GLENIE, R. C., and REED, K. J., 1960. Bores 2 and 3, Portland, Victoria. Subsurface geology and engineering data. *Vict. Mining and Geol. J.* 6 (4): 37-43.
- HARRIS, R. W., and McNULTY, C. L., 1956. Notes concerning a Senonian valvulinarian. *J. Paleont.* 30 (4): 865-868.
- HOFER, J., 1957. Foraminiferen der Oberkreide von Nordwestdeutschland und Holland. *Beih. geol. Jb.* 27: 1-464.
- , 1958. Taxonomic position of the Genus *Colomia* Cushman & Bermudez, 1948. *Contr. Cushman Fdn.* 9 (2): 34-35.
- , 1961. The gens *Globigerina* *cretacea* in north-western Europe. *Micropalaeontology* 7 (1): 95-100.
- JEFFERIES, R. P. S., 1962. Palaeoecology of the *Actinocamax plenus* subzone (lowest Turonian) in the Anglo-Paris Basin. *Palaeontology* 4 (4): 609-647.
- KENLEY, P. R., 1951. Marine Eocene sediments near Casterton, Victoria. *Aust. J. Sci.* 14 (3): 19.
- , 1954. The occurrence of Cretaceous sediments in southwestern Victoria. *Proc. Roy. Soc. Vict.* 66: 1-16.
- , 1959. The occurrence of marine Cretaceous sediments in the Belfast No. 4 Bore, Port Fairy. *Vict. Mining & Geol. J.* 6 (3): 55-56.
- KLAUS, J., 1959. Le 'Complex schisteux intermédiaire' dans le synclinal de la Gruyère (Pre Alpes Médiannes). Stratigraphie et micropaléontologie avec l'étude spéciale des Globotruncanides de l'Albien, du Cenomanien et du Turonien. *Ecol. Geol. Helv.* 52 (2).
- KLEINPELL, R. M., 1938. Miocene stratigraphy of California. *Am. Assoc. Pet. Geol.* 450 p.
- LOEBLICH, A. R., and TAPPAN, H., 1961. Cretaceous planktonic Foraminifera: Part I, Cenomanian. *Micropalaeontology* 7 (3): 257-304.
- LOWENSTAM, H. A., and EPSTEIN, S., 1959. Cretaceous paleo-temperatures as determined by oxygen isotope methods; their relation to, and the nature of, rudistid reefs. *20th Congresso geol. Internat. Mexico, El Sistema Cretacico* 1: 65-76.
- LOWMAN, S. W., 1949. Sedimentary facies in Gulf Coast. *Bull. Am. Assoc. Petrol. Geol.* 33 (12): 1939.
- MACFADYEN, W. A., 1933. Fossil Foraminifera from the Burwood Bank and their geologic significance. *Discovery Rept.* 7.
- MCQUEEN, A. F., 1961. The Geology of the Otway Basin. *Aust. Oil & Gas. J.* 8 (2): 8-13.
- MOULLADE, M., 1960. Foraminifères du Crétacé inférieur de la Drome. *Revue de Micropal.* 3 (2): 131-142.
- MULLER, S. M., and SCHENCK, H. G., 1943. Standard of the Cretaceous System. *Bull. Am. Assoc. Petrol. Geol.* 27 (3): 262-278.
- PHLEGER, F. B., 1960. *Ecology and Distribution of Recent Foraminifera*. John Hopkins Press, Baltimore.
- POKORNÝ, V., 1958. *Grundzüge der Zoologischen Mikropaläontologie Band. I*, D.V.W. Berlin.
- SIMPSON, G. G., 1961. *Principles of Animal Taxonomy*. Columbia Univ. Press, New York.
- SOHN, I. G., 1956. The transformation of opaque calcium carbonate to translucent calcium fluoride in fossil Ostracoda. *J. Paleont.* 30 (1): 113-114.
- STAINFORTH, R. M., 1952. Ecology of arenaceous Foraminifera. *The Micropaleontologist* 6 (1): 42-44.
- STELCK, C. R., and WALL, J. H., 1954. Kaskapau Foraminifera from Peace River area, western Canada. *Research Council Alberta, Rept.* 68.
- TAKAYANAGI, Y., 1960. Cretaceous Foraminifera from Hokkaido, Japan. *Sci. Repts. Tohoku Uni., Japan, 2nd Ser. (Geology)* 32 (1).
- TAPPAN, H., 1957. New Cretaceous index Foraminifera from Northern Alaska. *U.S. Nat. Mus. Bull.* 215: 201-222.
- , 1960. Cretaceous biostratigraphy from Northern Alaska. *Bull. Am. Assoc. Petrol. Geol.* 44 (3): 273-297.
- TEICHERT, C., 1958a. Some biostratigraphic concepts. *Bull. Geol. Soc. Am.* 69 (1): 99-120.

- , 1958b. Concepts of facies. *Bull. Am. Assoc. Petrol. Geol.* 42 (11): 2718-2744.  
 THOMAS, D. E., 1959. The geological structure of Victoria. *J. & Proc. Roy. Soc. N.S.W.* 92: 182-190.  
 WELLMAN, W. H., 1959. Divisions of the New Zealand Cretaceous. *Trans. Roy. Soc. N.Z.* 87 (1 & 2): 99-163.

### Explanation of Plates

#### PLATE LXXIX

- Fig. 1-2—*Hyperammmina elongata* Brady. (1) GSM 58716, complete specimen,  $\times 33$ ; (2) GSM 58717, usual preservation,  $\times 48$ .  
 Fig. 3—*Haplophragmoides* sp. A. GSM 58713, 3a, side view; 3b, edge view;  $\times 33$ .  
 Fig. 4—*Haplophragmoides* sp. B. GSM 58715, 4a, side view; 4b edge view;  $\times 33$ .  
 Fig. 5—*Haplophragmoides* sp. C. GSM 58714, 5a, side view; 5b, edge view;  $\times 33$ .  
 Fig. 6—*Ammobaculites goodlandensis* Cushman & Alexander. GSM 58675, side view,  $\times 33$ .  
 Fig. 7-9—*Ammobaculites subcretacea* Cushman & Alexander. (7) GSM 58676, side view,  $\times 33$ ; (8) GSM 58677, side view,  $\times 33$ ; (9) GSM 58678, side view—abnormal specimen,  $\times 33$ .  
 Fig. 10-11—*Ammobaculites* cf. *fragmentaria* Cushman. (10) GSM 58674, side view,  $\times 33$ ; (11) GSM 58673, side view,  $\times 23$ .  
 Fig. 12-15—*Textularia anceps* Reuss. (12) GSM 58741, microspheric form; 12a, side view; 12b, edge view; 12c, apertural view;  $\times 48$ . (13) GSM 58743, megalospheric form; 13a, side view; 13b, apertural view;  $\times 33$ . (14) GSM 58744, megalospheric form; 14a, side view; 14b, edge view; 14c, apertural view;  $\times 33$ . (15) GSM 58742, microspheric form; 15a, side view; 15b, apertural view;  $\times 48$ .  
 Fig. 16-17—*Textularia trilobita* sp. nov. (16) GSM 58748, Holotype; 16a, side view with terminal chamber overlapping; 16b, opposite side view; 16c, edge view; 16d, apertural view;  $\times 33$ . (17) GSM 58747, supplementary specimen C—juvenile; 17a, side view; 17b, apertural view;  $\times 48$ .

#### PLATE LXXX

- Fig. 1-2—*Textularia semicomplanata* Carsey. (1) GSM 58745, side view,  $\times 48$ ; (2) GSM 58746, 2a, side view; 2b, apertural view;  $\times 48$ .  
 Fig. 3—*Dorothia conulus* (Reuss). GSM 58698, 3a, side view; 3 b, apertural view;  $\times 48$ .  
 Fig. 4—*Dorothia filiformis* (Berthelin). GSM 58697, 4a, side view; 4b, apertural view;  $\times 48$ .  
 Fig. 5-7—*Marssonella oxycona* (Reuss). (5) GSM 58725, 5a, side view; 5b, apertural view;  $\times 48$ ; (6) GSM 58724, 6a, side view,  $\times 33$ ; (7) GSM 58723, 7a, side view; 7b, end view;  $\times 48$ .  
 Fig. 8—*Cornuspira involvens* (Reuss). GSM 58694, side view,  $\times 48$ .  
 Fig. 9-10—*Cornuspira subprimitiva* Bartenstien & Brand. (9) GSM 58695, 9a, side view; 9b, edge view;  $\times 73$ ; (10) GSM 58693, acidized specimen, side view,  $\times 73$ .  
 Fig. 11—*Quinqueloculina* sp. GSM 58737, 11a, edge view; 11b, side view; 11c, apertural view;  $\times 48$ .  
 Fig. 12-13—*Nodosaria obscurra* Reuss. (12) GSM 58732, slender form, side view; (13) GSM 58731, broad form, 13a, side view; 13b, apertural view;  $\times 48$ .  
 Fig. 14—*Nodosaria* cf. *obscurra* Reuss. GSM 58730, side view,  $\times 73$ .  
 Fig. 15-16—*Nodosaria alternistriata* Morrow. (15) GSM 58727, 15a, side view; 15b, apertural view;  $\times 48$ ; (16) GSM 58726, side view,  $\times 60$ .  
 Fig. 17-18—*Nodosaria navarroana* Cushman. (17) GSM 58729, 17a, side view; 17b, apertural view;  $\times 48$ ; (18) GSM 58728, side view,  $\times 48$ .  
 Fig. 19—*Dentalina* cf. *intrasegma* (Carsey). GSM 58696, side view,  $\times 48$ .

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- Fig. 1-3—*Lenticulina (Robulus) navarroensis* (Plummer). (1) GSM 58738, 1a, side view; 1b, edge view;  $\times 17$ ; (2) GSM 58739, side view,  $\times 9$ ; (3) GSM 58740, 3a, side view; 3b, edge view;  $\times 17$ .  
 Fig. 4-5—*Lenticulina (Marginulinopsis) curvisepta* Cushman & Goudkoff. (4) GSM 58720, side view,  $\times 33$ ; (5) GSM 58721, 5a, side view; 5b, apertural view;  $\times 33$ .  
 Fig. 6—*Lenticulina (Marginulinopsis) jarvisi* (Cushman). GSM 58722, 6a, side view; 6b, apertural view;  $\times 33$ .  
 Fig. 7-8—*Marginulina inaequalis* Reuss. (7) GSM 58718, 7a, side view; 7b, edge view;  $\times 48$ ; (8) GSM 58719, 8a, side view; 8b, edge view;  $\times 48$ .  
 Fig. 9—*Citharina whangaia*. GSM 58688, 9a, side view; 9b, apertural margin; 9c, outer margin;  $\times 33$ .

- Fig. 10—*Citharina geisendoerferi* (Frankc). GSM 58687, 10a, side view; 10b, edge view;  $\times 73$ .  
 Fig. 11-12—*Frondicularina* cf. *mucronata* Reuss. (11) GSM 58699, fragment-apertural end,  $\times 33$ ; (12) GSM 58700, fragment-basal end,  $\times 33$ .  
 Fig. 13—*Frondicularia* sp. GSM 58701, 13a, edge view; 13b, side view;  $\times 73$ .  
 Fig. 14—*Globulina lacrima* Reuss. GSM 58703, 14a, edge view; 14b, side view; 14c, basal view;  $\times 48$ .  
 Fig. 15—*Praeulimina ovulum* (Reuss). GSM 58736, 15a, side view; 15b, apertural view;  $\times 120$ .  
 Fig. 16—*Buliminella* cf. *parvula* Brotzen. GSM 58679, 16a, side view; 16b, front view;  $\times 120$ .

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- Fig. 1-4—*Colomia austrotrochus* sp. nov. (1) GSM 58691, holotype; 1a, front view; 1b, opposite side view;  $\times 73$ ; (2) GSM 58690, supplementary specimen A; 2a, side view; 2b, apertural view;  $\times 48$ ; (3) GSM 58692, supplementary specimen B; 3a, side view; 3b, apertural view;  $\times 73$ ; (4) GSM 58689, supplementary specimen C; 4a, front view; 4b, side view;  $\times 73$ .  
 Fig. 5—*Allomorphina pyriformis* sp. nov. GSM 58673, Holotype; 5a, spiral view; 5b, umbilical view; 5c, edge view;  $\times 48$ .  
 Fig. 6-7—*Pallaimorphina heliciformis* sp. nov. (6) GSM 58734, Holotype; 6a, spiral view; 6b, umbilical view; 6c, edge view;  $\times 105$ ; (7) GSM 58733, supplementary specimen; 7a, spiral view; 7b, umbilical view; 7c, edge view;  $\times 105$ .  
 Fig. 8—*Stilostomella alexanderi* (Cushman). GSM 58752, side view,  $\times 48$ .  
 Fig. 9—*Pleurostomella subnodosa* Reuss. GSM 58753, 9a, front view; 9b, side view;  $\times 42$ .  
 Fig. 10—*Valvulineria lenticula* (Reuss). GSM 58751, 10a, spiral view; 10b, umbilical view; 10c, edge view;  $\times 105$ .  
 Fig. 11—*Valvulineria undulata* Belford. GSM 58750, 11a, spiral view; 11b, umbilical view; 11c, edge view;  $\times 105$ .  
 Fig. 12—*Valvulineria erugata* Belford. GSM 58749, 12a, spiral view; 12b, umbilical view; 12c, edge view;  $\times 105$ .

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- Fig. 1—*Gyroidinoides nitida* (Reuss). GSM 58707, 1a, spiral view; 1b, umbilical view; 1c, edge view;  $\times 73$ .  
 Fig. 2—*Gyroidinoides cruachin* sp. nov. GSM 58708, Holotype; 2a, spiral view; 2b, umbilical view; 2c, edge view;  $\times 73$ .  
 Fig. 3-4—*Alabonina australis* Belford. (3) GSM 58670, 4a, spiral view; 4b, umbilical view; 4c, edge view;  $\times 105$ ; (4) GSM 58671, 4a, spiral view; 4b, umbilical view; 4c, edge view;  $\times 120$ .  
 Fig. 5-6—*Cibicides excavatus* Brotzen. (5) GSM 58684, 5a, spiral view; 5b, umbilical view; 5c, edge view;  $\times 48$ ; (6) GSM 58685, spiral view,  $\times 48$ .  
 Fig. 7—*Cibicides ribbingi* Brotzen. GSM 58682, 7a, spiral view; 7b, umbilical view; 7c, edge view;  $\times 33$ .  
 Fig. 8—*Hanzawaia californica* (Bandy). GSM 58686, 8a, spiral view; 8b, umbilical view; 8c, edge view;  $\times 105$ .  
 Fig. 9—*Gavelinopsis cenomanica* (Brotzen). GSM 58702, 9a, dorsal view; 9b, ventral view; 9c, edge view;  $\times 48$ .  
 Fig. 10—*Gavelinopsis* cf. *eriksdalensis* Brotzen. GSM 58705, 10a, dorsal view; 10b, ventral view; 10c, edge view;  $\times 73$ .

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- Fig. 1-2—*Ceratobulimina krennoides* sp. nov. (1) GSM 58680, Holotype; 1a, spiral view; 1b, umbilical view; 1c, edge view;  $\times 48$ ; (2) GSM 58681, supplementary specimen; 2a, spiral view; 2b, umbilical view; 2c, edge view;  $\times 48$ .  
 Fig. 3—*Ceratobulimina cretacea* Cushman & Harris. GSM 58682, 3a, spiral view; 3b, umbilical view; 3c, edge view;  $\times 73$ .  
 Fig. 4-7—*Hedbergella trocoidea* (Gandolfi). (4) GSM 58709 (fluorite replacement); 4a, spiral view; 4b, umbilical view; 4c, edge view;  $\times 105$ ; (5) GSM 58711, 5a, spiral view; 5b, umbilical view; 5c, edge view;  $\times 73$ ; (6) GSM 58712 (calcite mould); 6a, spiral view; 6b, umbilical view; 6c, edge view;  $\times 73$ ; (7) GSM 58710 (fluorite replacement); spiral view;  $\times 105$ .  
 Fig. 8—*Guembelina reussi* Cushman. GSM 58706, 8a, side view; 8b, edge view;  $\times 73$ .  
 Fig. 9—*Hoeglundina supracretacea* (ten Dam). GSM 58704, 9a, spiral view; 9b, umbilical view; 9c, edge view;  $\times 73$ .



## PLATE LXXXV

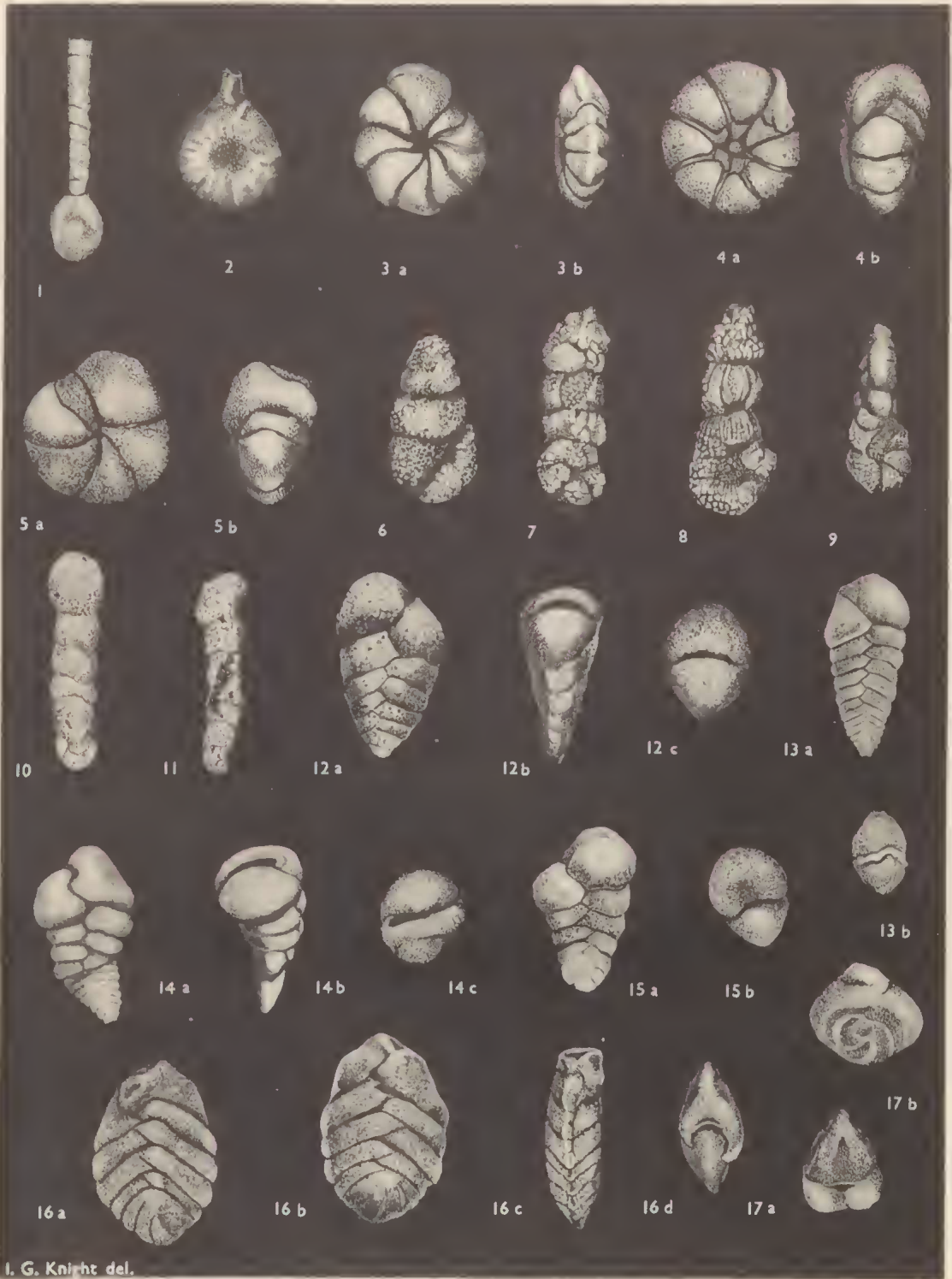
(Photomicrographs of thin sections)

- Fig. 1—*Textularia semicomplanata* Carsey. GSM 58803, longitudinal section—under crossed nicols,  $\times 80$ .  
Fig. 2-3—*Textularia anceps* Reuss. (2) GSM 58802, microspheric specimen, longitudinal section—under crossed nicols,  $\times 80$ ; (3) GSM 58801, megalospheric specimen, longitudinal section—under crossed nicols,  $\times 80$ .  
Fig. 4-5—*Textularia trilobita* sp. nov. (4) GSM 58804, supplementary specimen A—microspheric form, longitudinal section, 4a, under crossed nicols; 4b, normal;  $\times 50$ ; (5) GSM 58805, supplementary specimen B—megalospheric specimen, longitudinal section—under crossed nicols,  $\times 50$ .

## PLATE LXXXVI

(Photomicrographs of thin sections)

- Fig. 1-3—*Colomia austrotrachus* sp. nov. (1) GSM 58793, supplementary specimen D, longitudinal section, 1a, normal; 1b, under crossed nicols;  $\times 80$ ; (2) GSM 58794, supplementary specimen E, longitudinal section—under crossed nicols,  $\times 80$ ; (3) GSM 58795, supplementary specimen F, thick transverse section towards initial end,  $\times 215$ .  
Fig. 4-5—*Cibicides excavatus* Brotzen. (4) GSM 58791, horizontal section—under crossed nicols,  $\times 80$ ; (5) GSM 58870, vertical section,  $\times 80$ .  
Fig. 6—*Alabamina australis* Belford. GSM 58790, horizontal section,  $\times 160$ .  
Fig. 7—*Hanzawaia californica* Bandy. GSM 58792, horizontal section,  $\times 200$ .  
Fig. 8-9—*Gavelinopsis cenomanica* Brotzen. (8) GSM 58797, vertical section,  $\times 80$ ; (9) GSM 58796, horizontal section,  $\times 80$ .



I. G. Knight del.